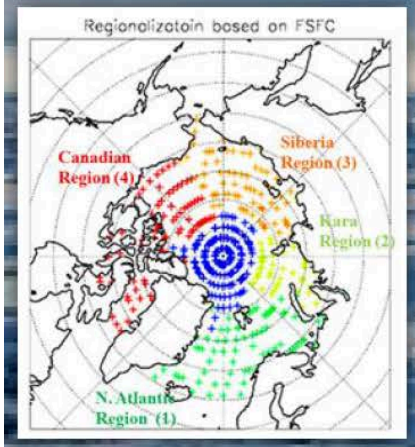
Department of GEOGRAPHY
College of Earth, Ocean, and Environment

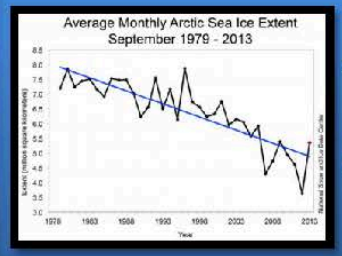
Fall 2014

# DISSERTATION DEFENSE

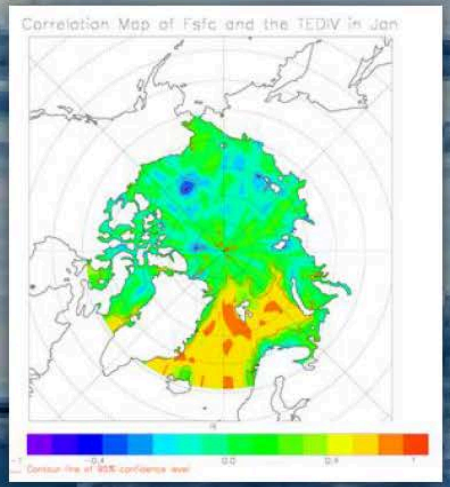

*Weihan Chan*
Graduate Student
Department of Geography
University of Delaware

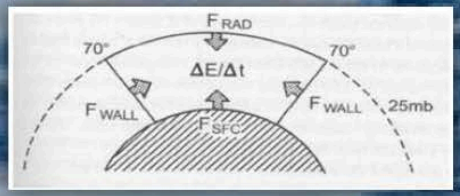

**Wednesday, October 29, 2014**
**11:00am**
**218 Pearson Hall**

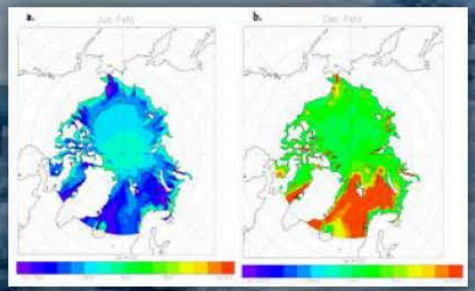



# The Arctic Energy Budget, Sea Ice Area, and the Atmospheric Circulation

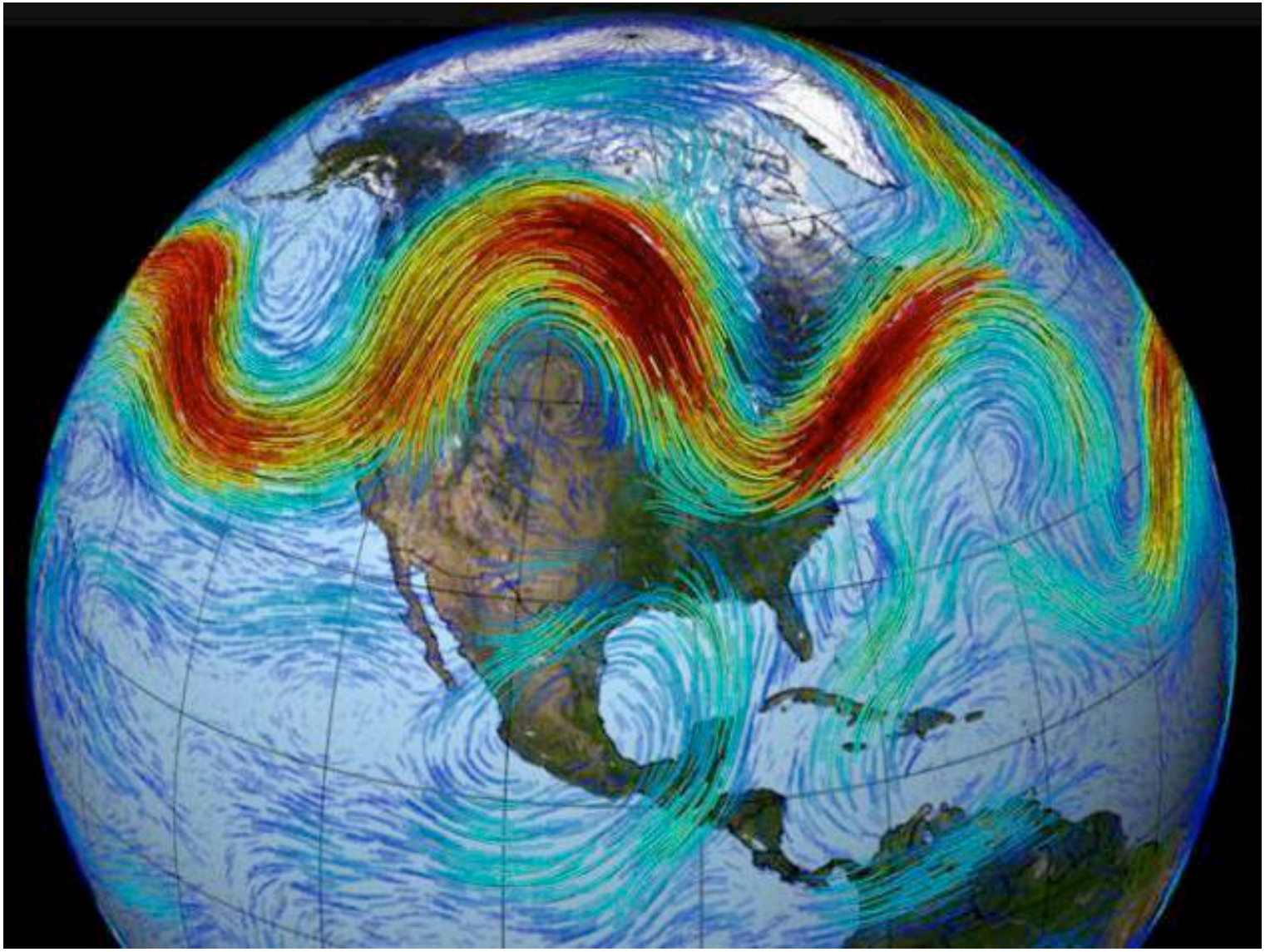


*This seminar is free and open to the public.*

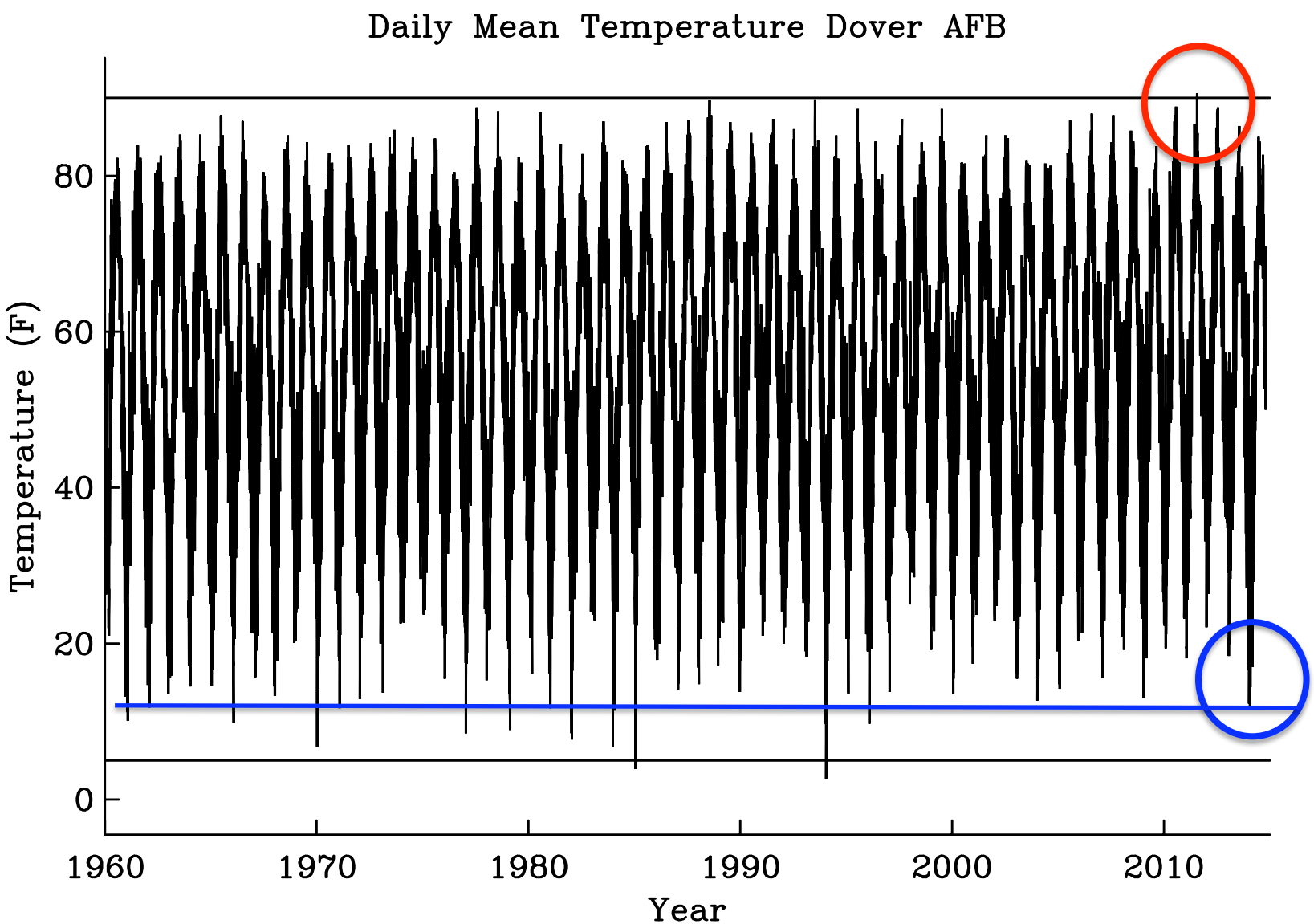
Does Arctic Amplification increase mid-latitude droughts, floods, heat waves, and cold snaps globally?



# Global Warming and Winter Weather

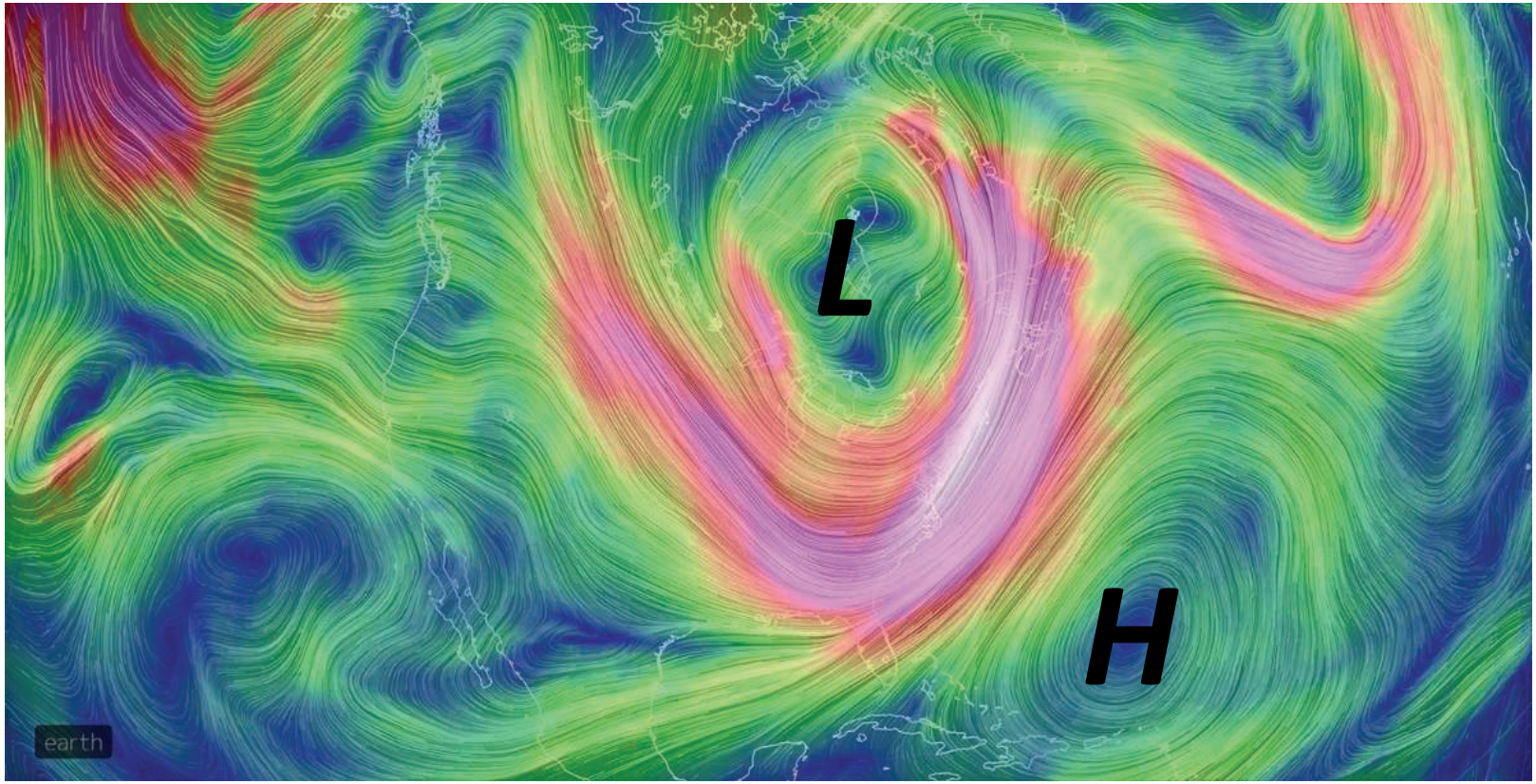
IN MID-JANUARY, A LOBE OF THE POLAR VORTEX SAGGED SOUTHWARD OVER THE CENTRAL and eastern United States. All-time low temperature records for the calendar date were set at O'Hare Airport in Chicago [–16°F (–27°C), 6 January], at Central Park in New York [4°F (–15.6°C), 7 January], and at many other stations (*1*). Since that event, several substantial snow storms have blanketed the East Coast. Some have been touting such stretches of extreme cold as evidence that global warming is a hoax, while others have been citing them as evidence that global warming is causing a "global weirding" of the weather. In our view, it is neither.

Wallace et al. (2014)


NCDC Raw Data

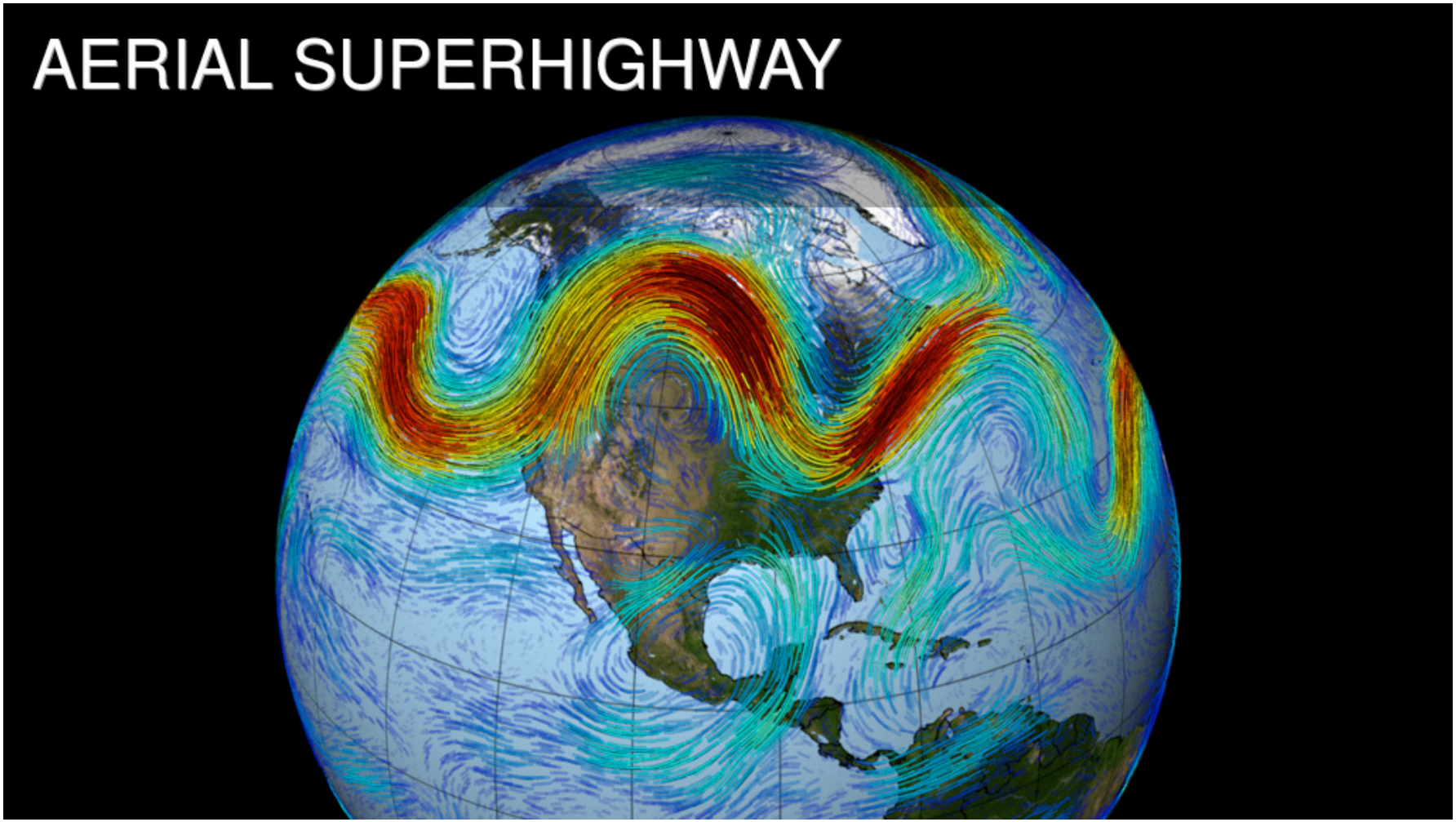
# Jan.-7, 2014 Jetstream over North-America --> “Polar Vortex”




**Icy blast.** Arctic winds flowed down to North America in January, causing record-breaking cold temperatures. Image shows streamlines of wind at the 500 mbar level at 1:00 a.m. Eastern Standard Time on 7 January 2014. Red indicates faster speeds.

Wallace et al. (2014)

# Jet Stream Visualization




June-10 through July-18, 1988
http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=3864

Polar Amplification
Extreme mid-latitude weather events more likely?

Less sea ice, more open water ✔ Yes

# Polar Amplification
# Extreme mid-latitude weather events more likely?

Less sea ice, more open water ✔ Yes

--> More heat flux from ocean to atmosphere ✔ Yes

# Polar Amplification
# Extreme mid-latitude weather events more likely?

Less sea ice, more open water ✔ Yes

--> More heat flux from ocean to atmosphere ✔ Yes

--> Arctic air warms faster than sub-Arctic air ✔ Yes

# Polar Amplification
# Extreme mid-latitude weather events more likely?

| | |
|---|---|
| Less sea ice, more open water | ✔ Yes |
| --> More heat flux from ocean to atmosphere | ✔ Yes |
| --> Arctic air warms faster than sub-Arctic air | ✔ Yes |
| --> Weakens N-S pressure gradient and E-W jetstream | ✔ Yes |

# Polar Amplification
# Extreme mid-latitude weather events more likely?

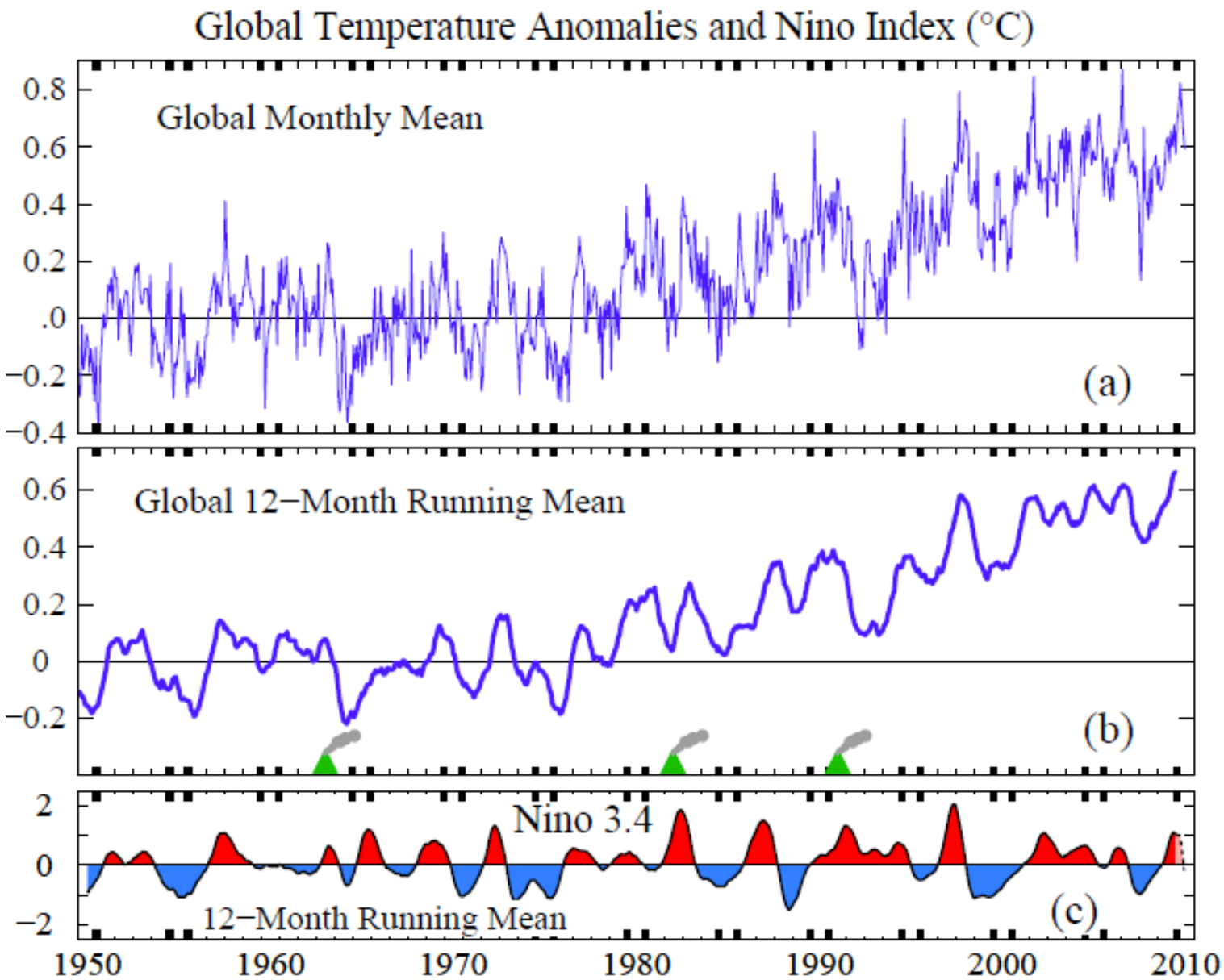
| | |
|---|---|
| Less sea ice, more open water | ✔ Yes |
| --> More heat flux from ocean to atmosphere | ✔ Yes |
| --> Arctic air warms faster than sub-Arctic air | ✔ Yes |
| --> Weakens N-S pressure gradient and E-W jetstream | ✔ Yes |
| --> Weaker jetstream has larger N-S meanders | ? maybe |

# Polar Amplification
# Extreme mid-latitude weather events more likely?

| | |
|---|---|
| Less sea ice, more open water | ✔ Yes |
| --> More heat flux from ocean to atmosphere | ✔ Yes |
| --> Arctic air warms faster than sub-Arctic air | ✔ Yes |
| --> Weakens N-S pressure gradient and E-W jetstream | ✔ Yes |
| --> Weaker jetstream has larger N-S meanders | ? maybe |
| --> Larger meanders move more slowly | ? maybe |

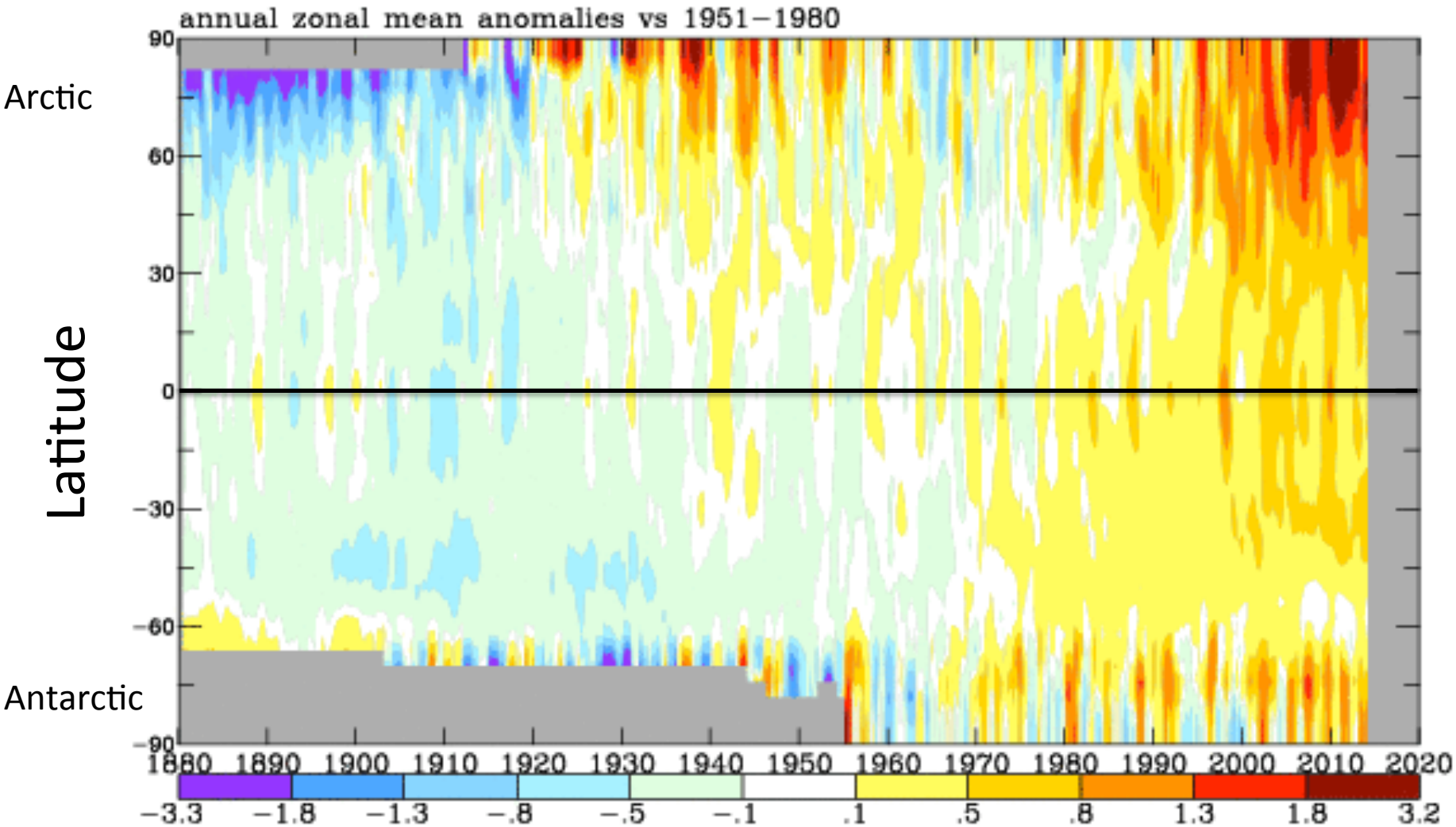
# Polar Amplification
# Extreme mid-latitude weather events more likely?

| | |
|---|---|
| Less sea ice, more open water | ✔ Yes |
| --> More heat flux from ocean to atmosphere | ✔ Yes |
| --> Arctic air warms faster than sub-Arctic air | ✔ Yes |
| --> Weakens N-S pressure gradient and E-W jetstream | ✔ Yes |
| --> Weaker jetstream has larger N-S meanders | ? maybe |
| --> Larger meanders move more slowly | ? maybe |
| --> Extreme weather events more frequent | maybe not |




Hansen et al. (2010)

**Combined Land-Surface Air and Sea-Surface Water Temperature Anomalies**

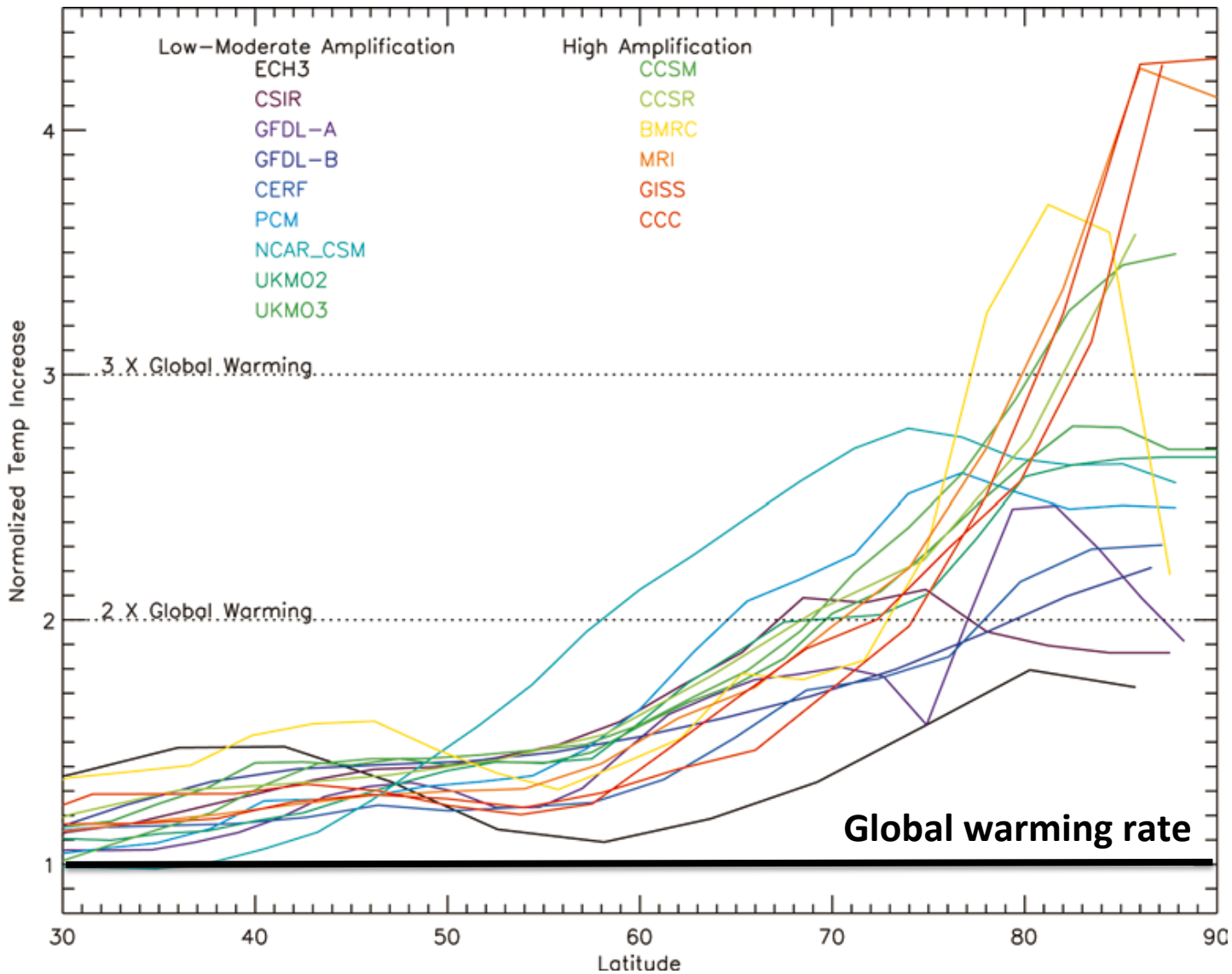



**NASA/GISS Surface Temperature Analysis**

# Model Results:

Holland and Bitz: Polar amplification of climate change in coupled models

Normalized Temperature Increase



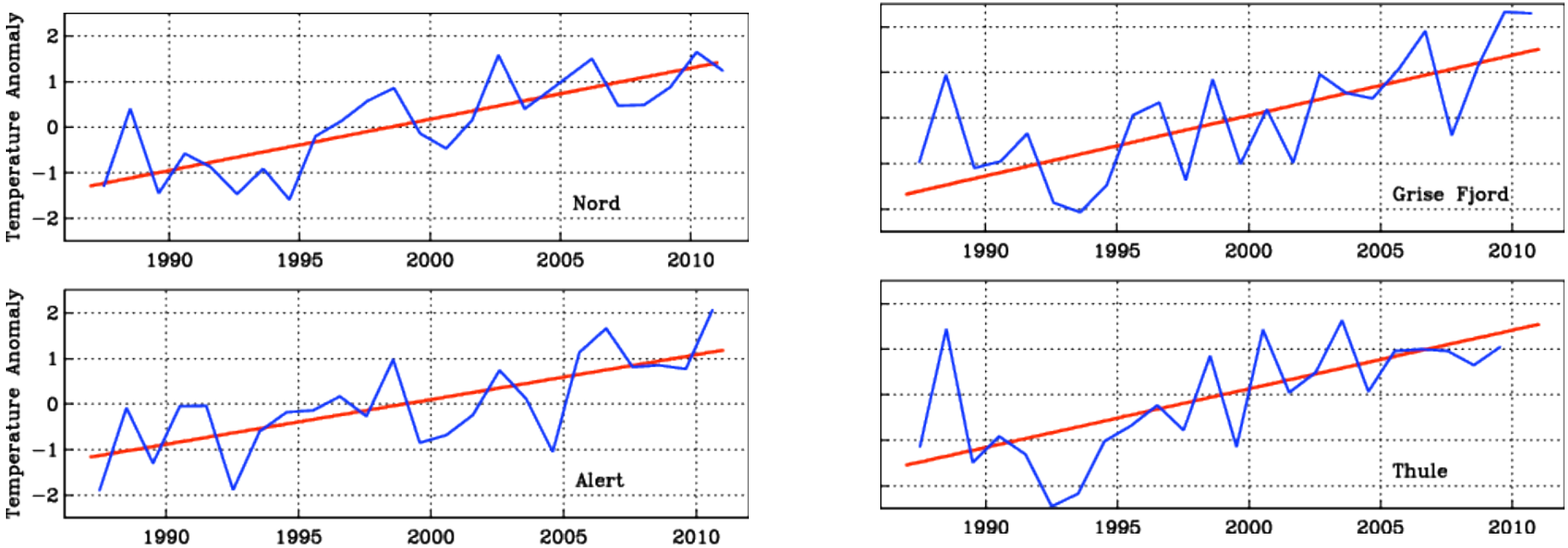

Latitude North

Holland and Bitz (2003)

***The air around northern Greenland and Ellesmere Island has warmed by about***

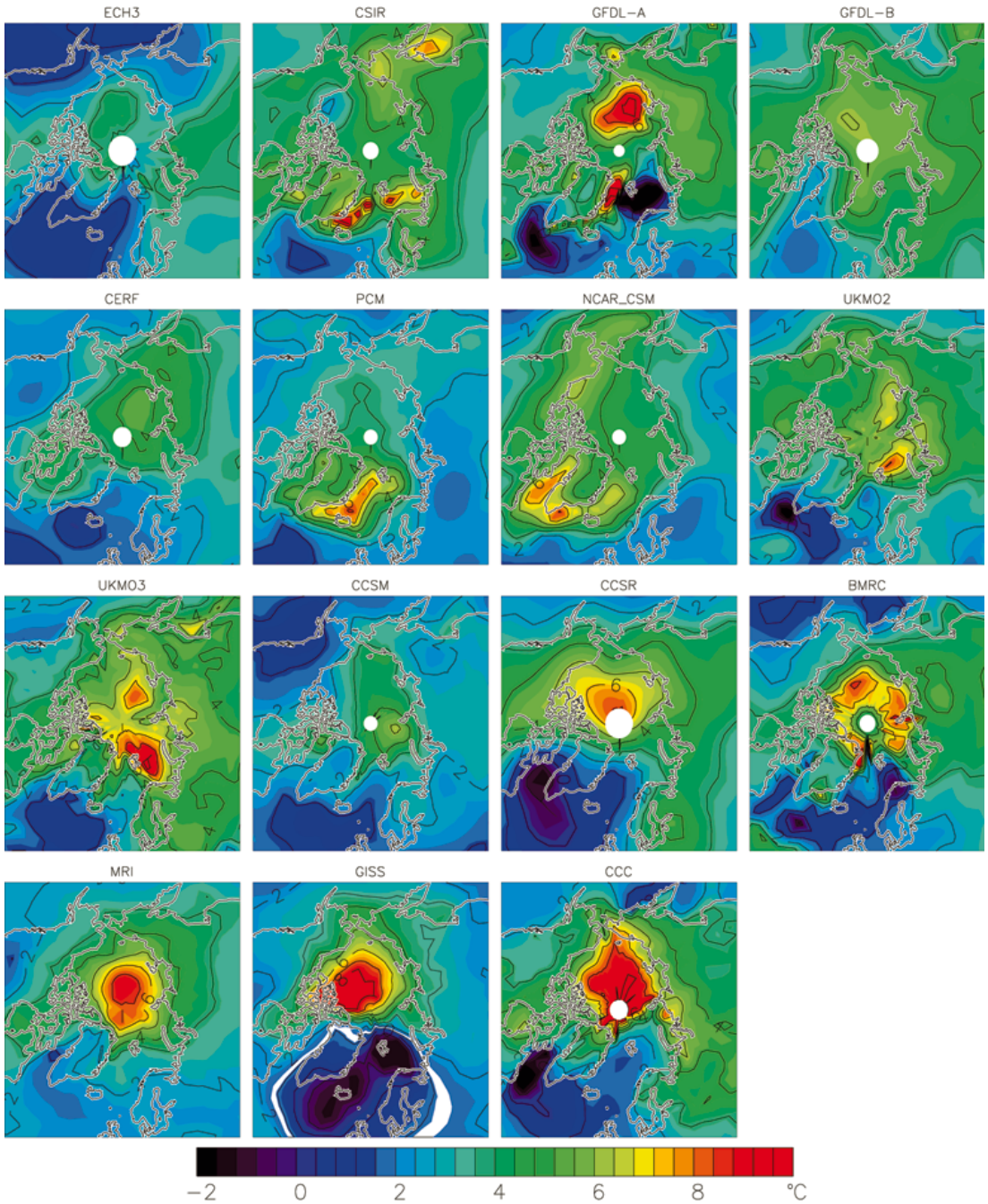
***1.1 +/- 0.25 degrees Celsius/decade****

***since 1987, more than five times faster than the rest of the world.***




(*) Screen (2014): 0.86° C/decade between 70-80 N

IcySeas.org Jun.-27, 2012




Air Temperature Change

Relative to global average

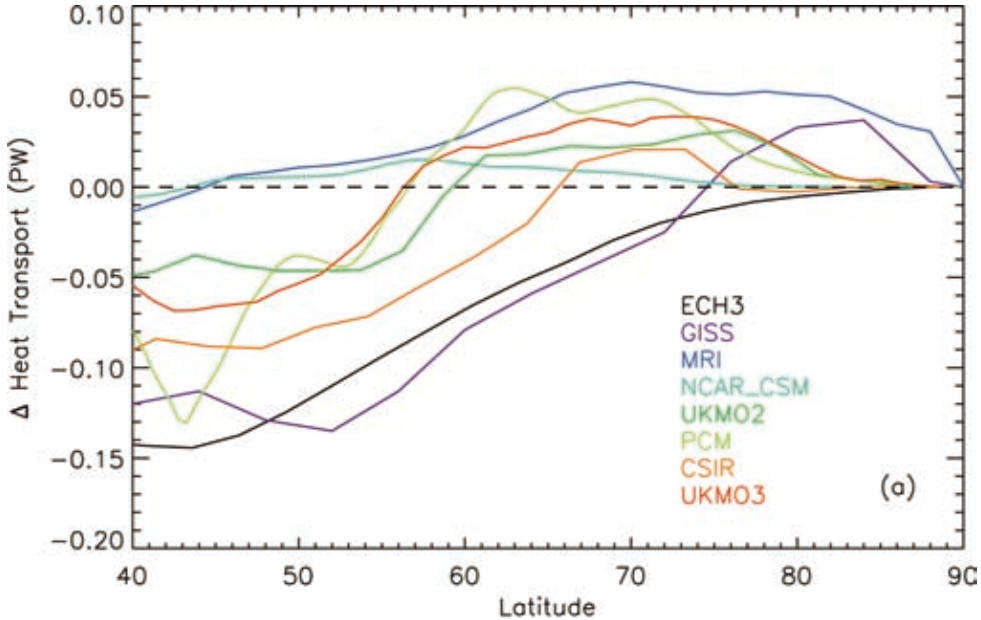
in 2x $CO_2$ experiments of

Ice-ocean-atmosphere

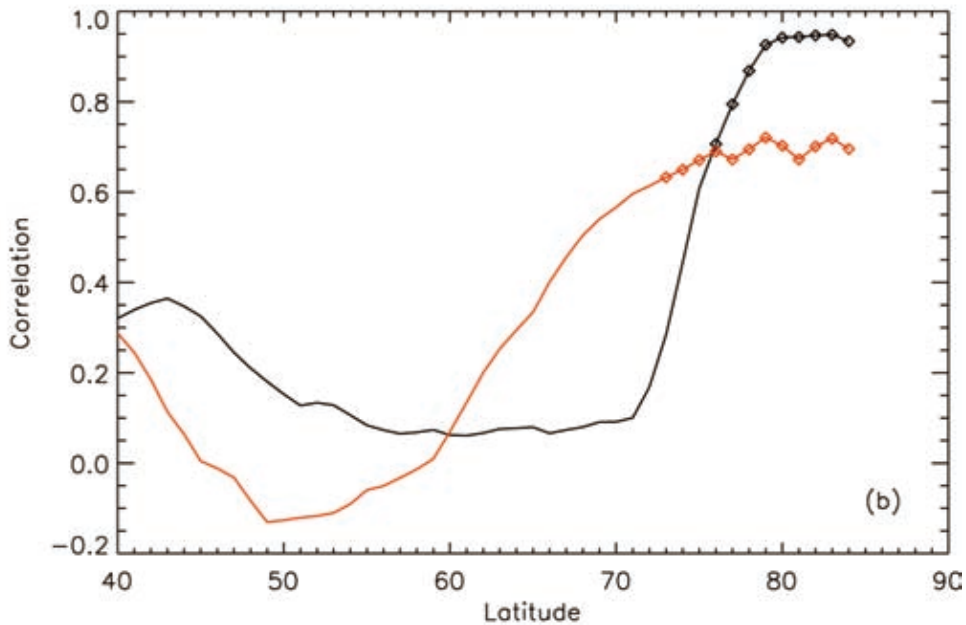
in 15 Coupled models

Holland and Bitz (2003)

Poleward Ocean Heat Transport




Correlation




Ocean Heat Transport

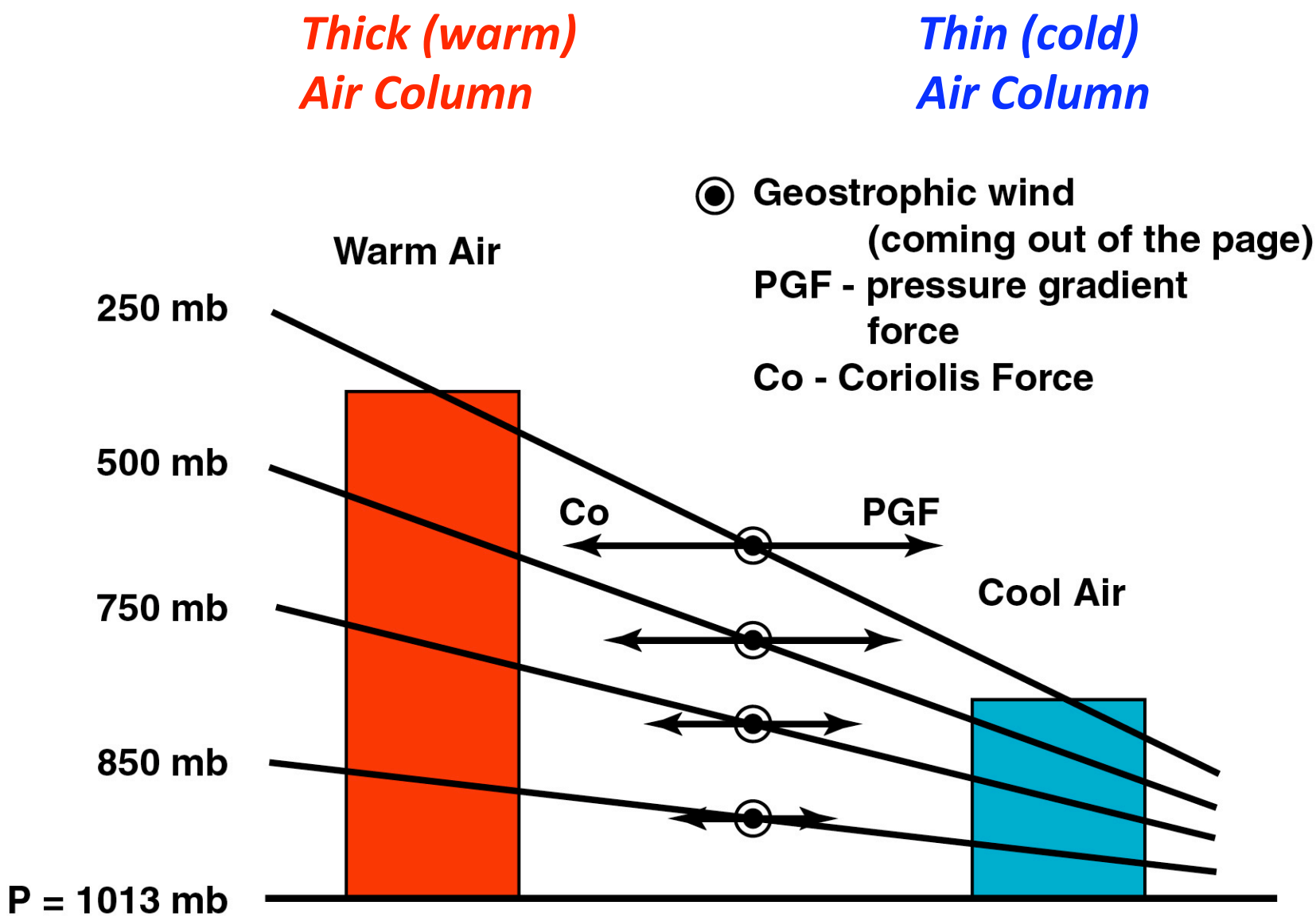
vs.

Air Temperature

Latitude

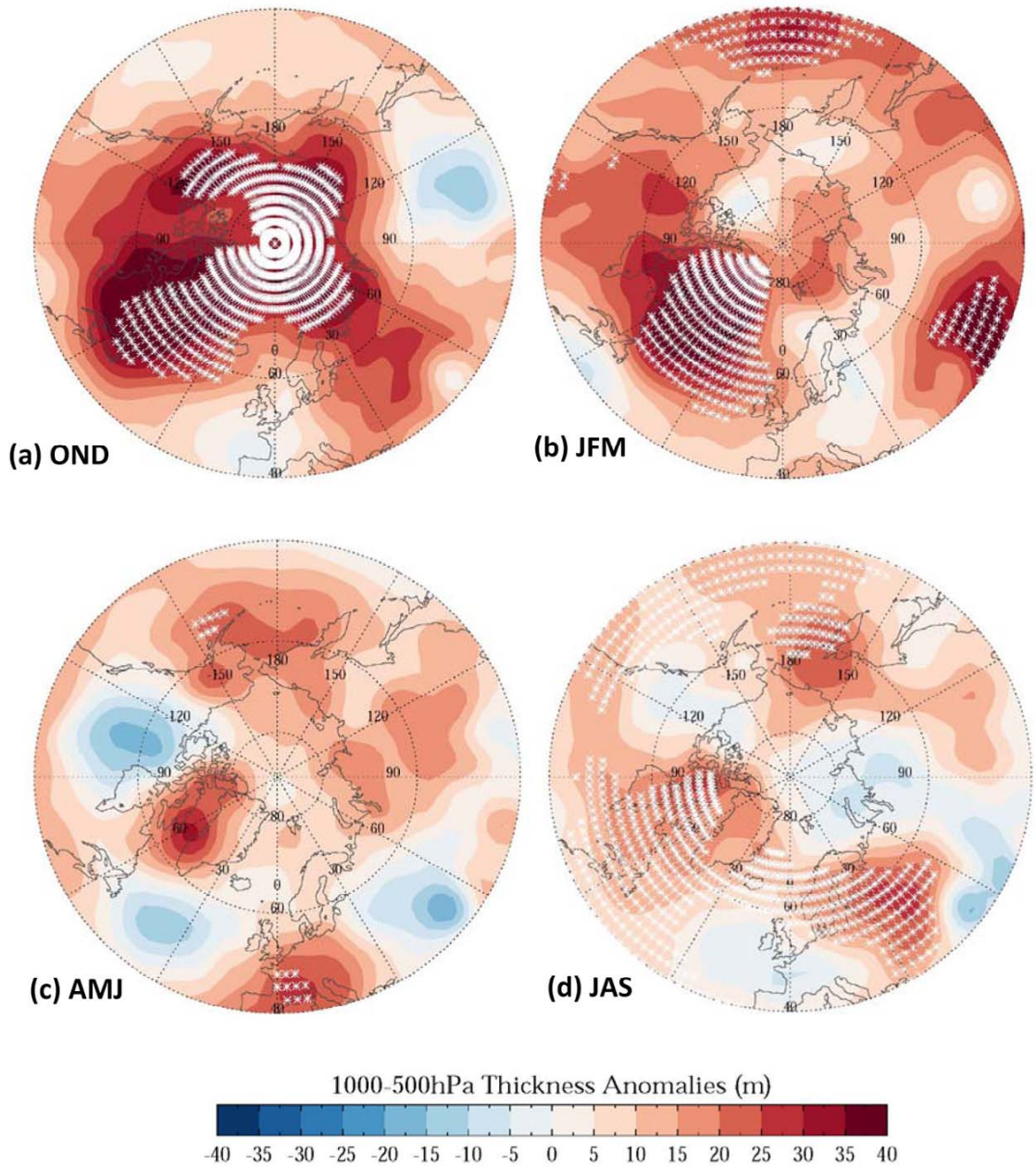
Holland and Bitz (2003)

# Geostrophic Balance – With Baroclinic Shear




http://www.ux1.eiu.edu/~cfjps/1400/pressure_wind.html

FRANCIS AND VAVRUS: ARCTIC LINKS TO MID-LATITUDE WEATHER

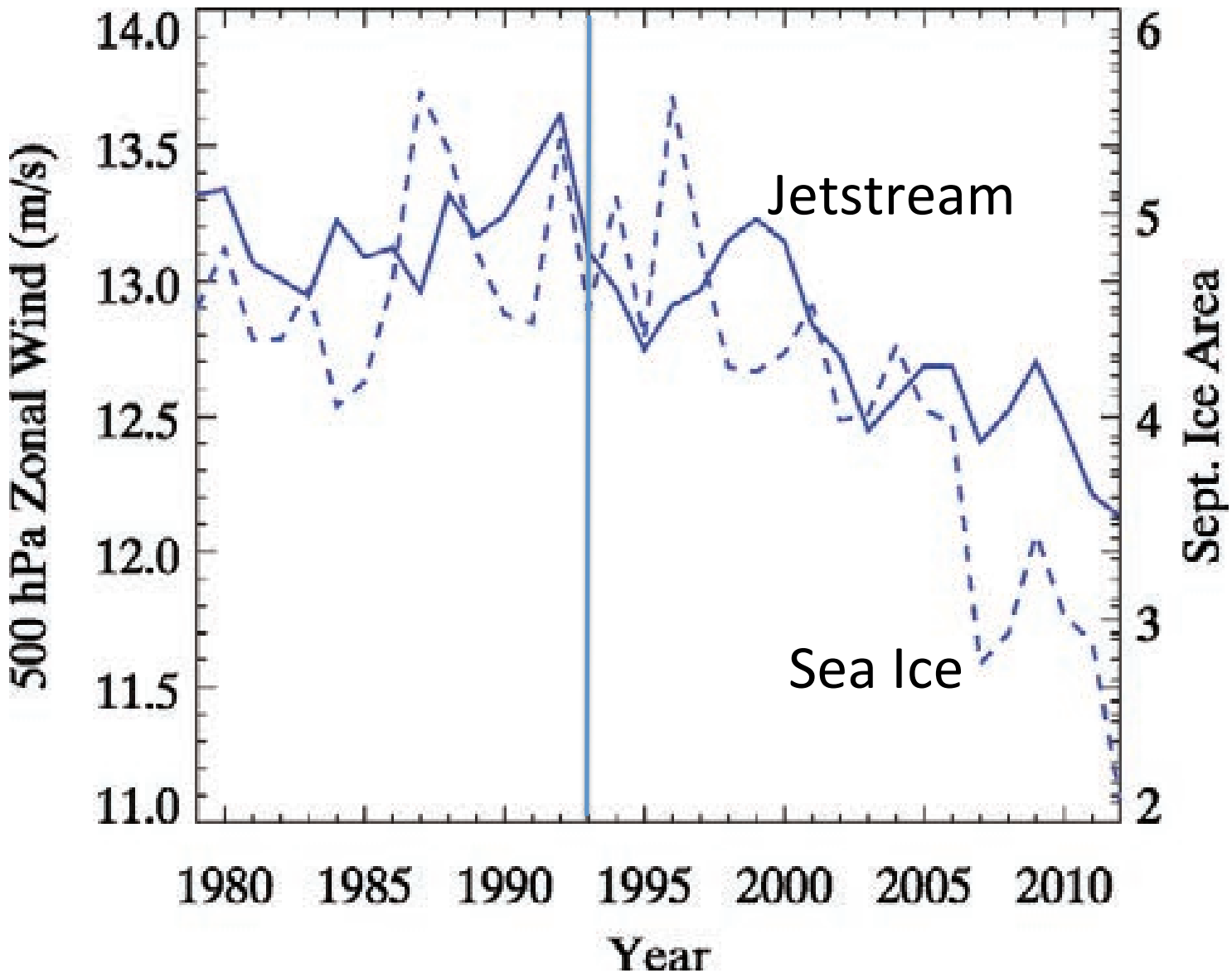



Arctic Air
Column Thickness
2000 to 2011
minus
1970 to 1999

Increased mostly
Fall and Winter

But regionally in
Spring and Summer
also

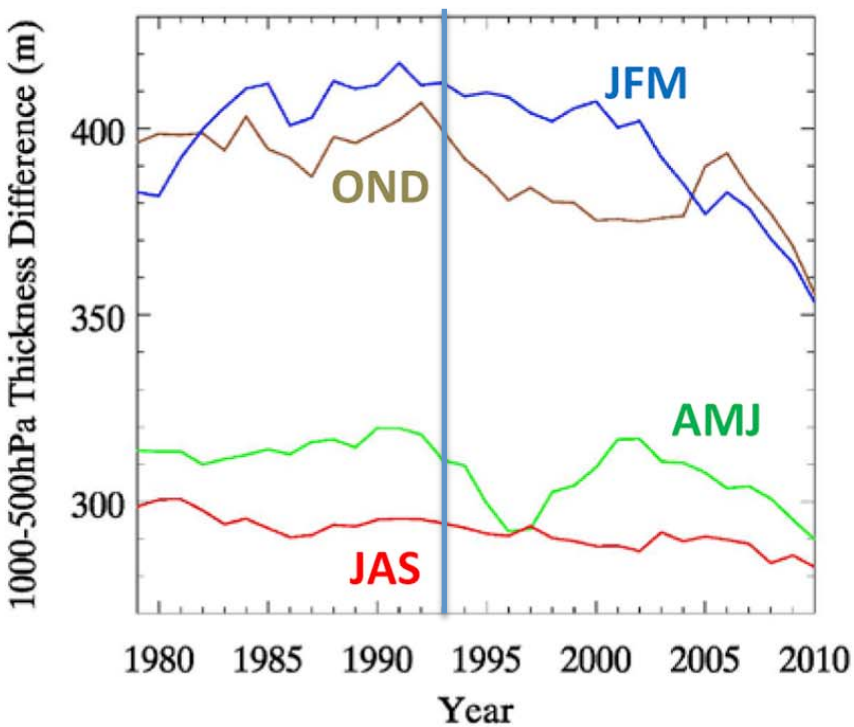
Francis and Vavrus (2012)



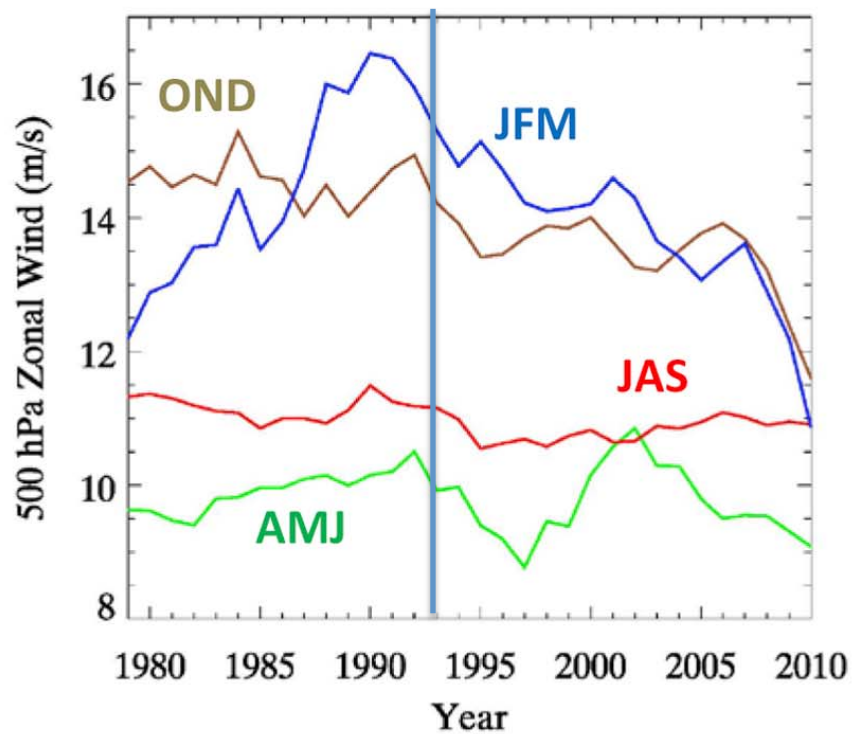

Francis (2014)

# Evolution of Thermal Wind

N-S Thickness Difference

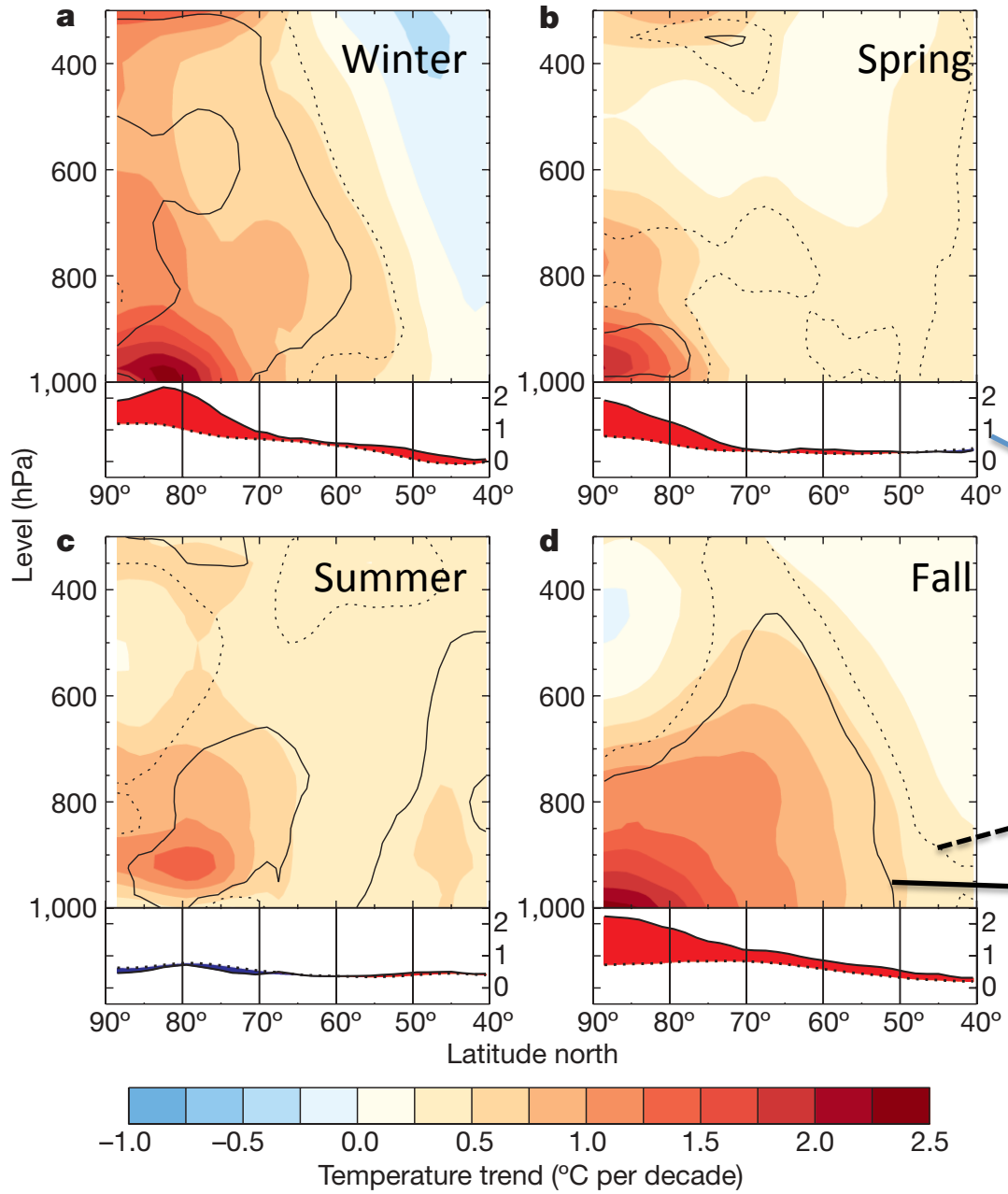



E-W Winds




Fall/Winter pressure gradients and winds weakening

Francis and Vavrus (2012)




Air Temperature Trends:

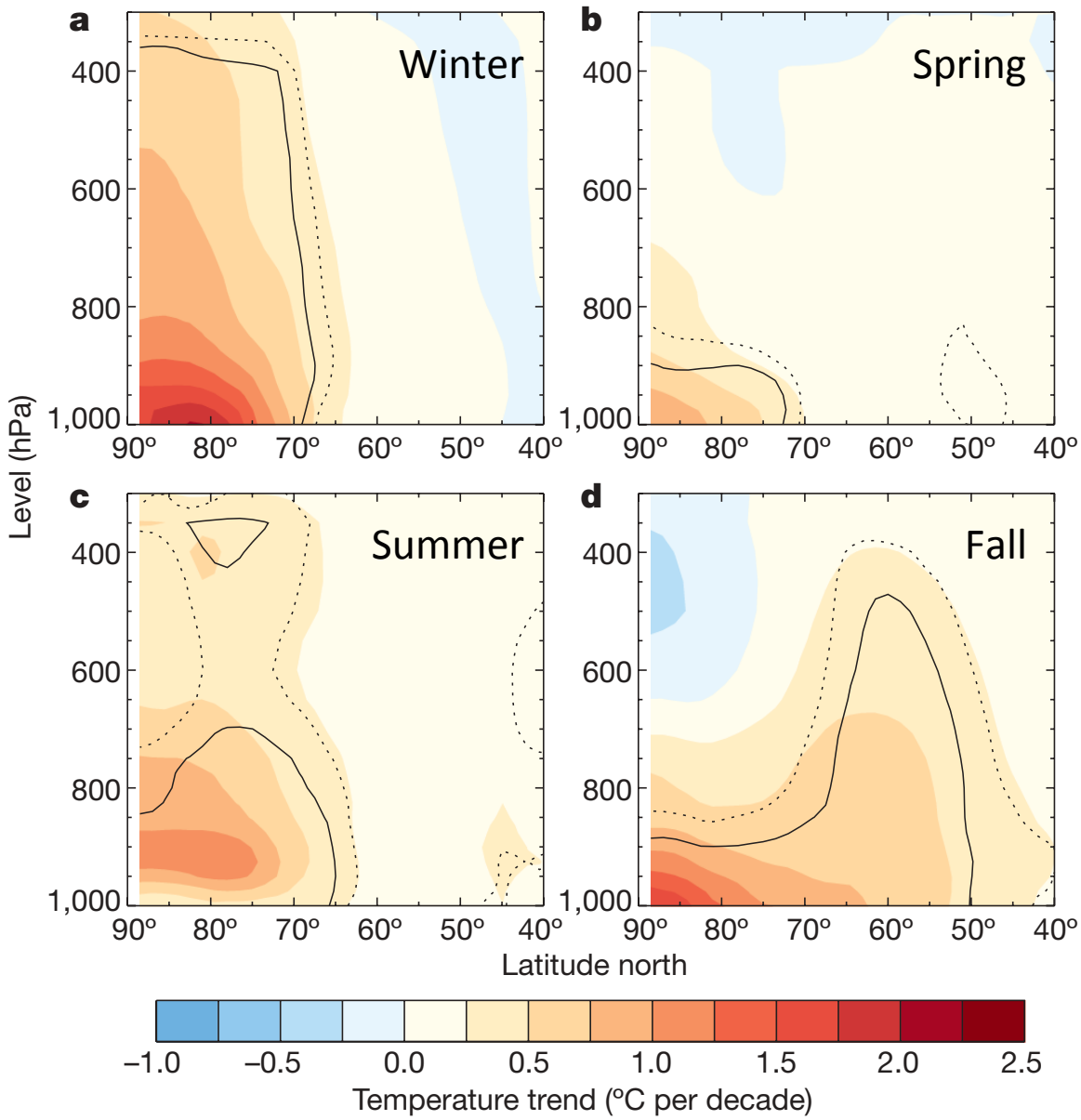
Warmer Arctic
Mostly fall/winter

Trends on
Vertical averages

95% confidence

99% confidence

Screen and Simmonds (2010)

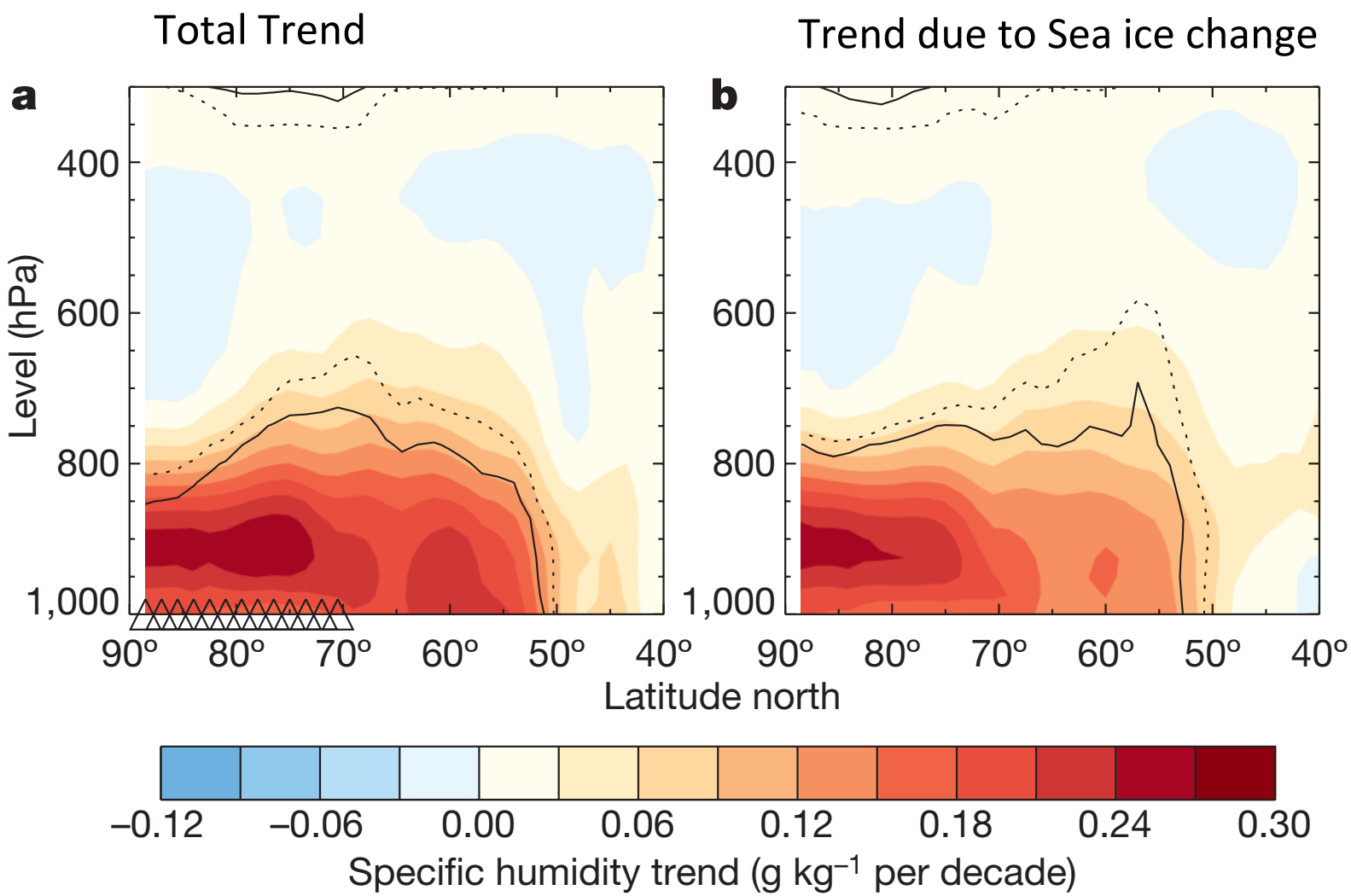



Air Temperature Trends due to Sea Ice Change:

… as sea ice cover diminishes

Screen and Simmonds (2010)

# Warmer Arctic due to reduced sea ice causes increased moisture

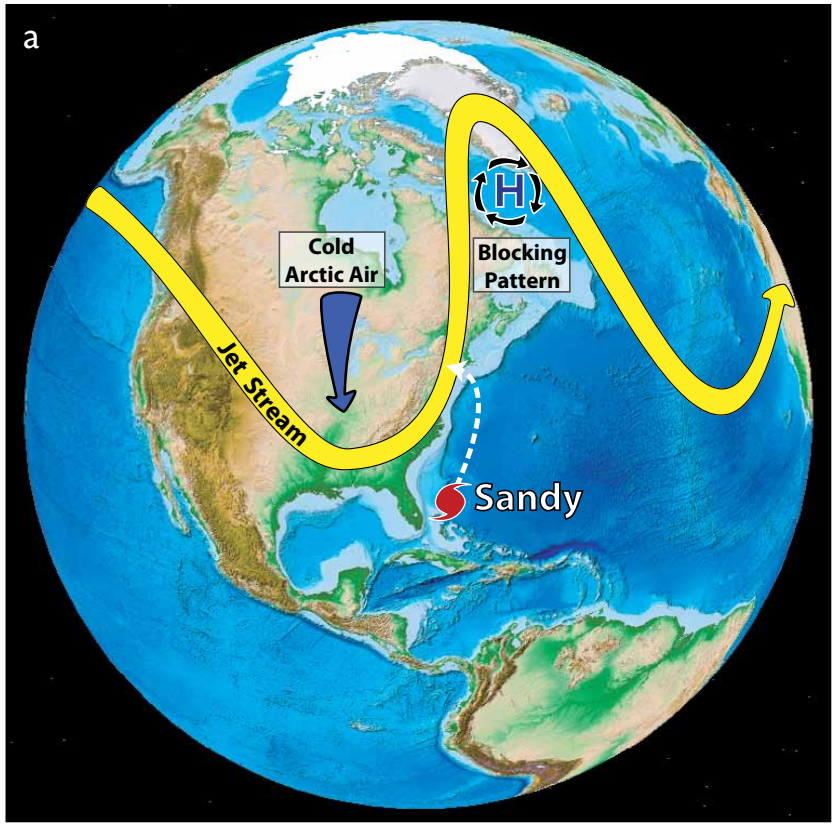



Screen and Simmonds (2010)

# Polar Amplification
# Extreme mid-latitude weather events more likely?

| | |
|---|---|
| Less sea ice, more open water | ✔ Yes |
| --> More heat flux from ocean to atmosphere | ✔ Yes |
| --> Arctic air warms faster than sub-Arctic air | ✔ Yes |
| --> Weakens N-S pressure gradient and E-W jetstream | ✔ Yes |
| --> Weaker jetstream has larger N-S meanders | ? maybe |
| --> Larger meanders move more slowly | ? maybe |
| --> Extreme weather events more frequent | maybe not |

# Hurricane Sandy 2012



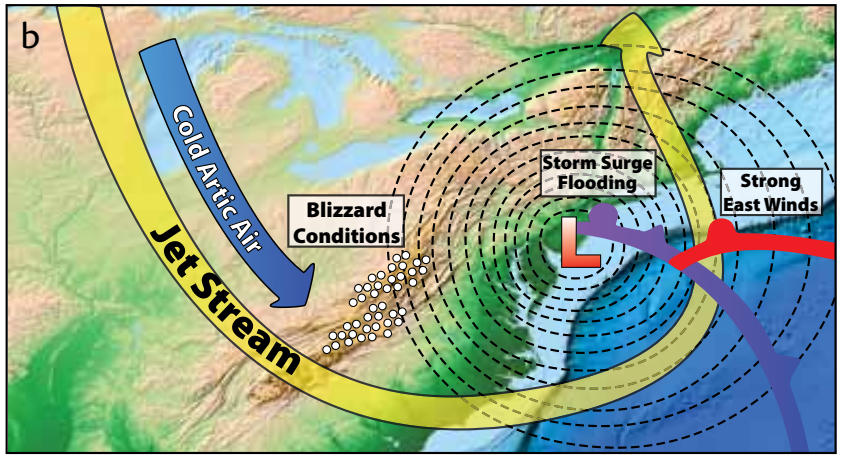
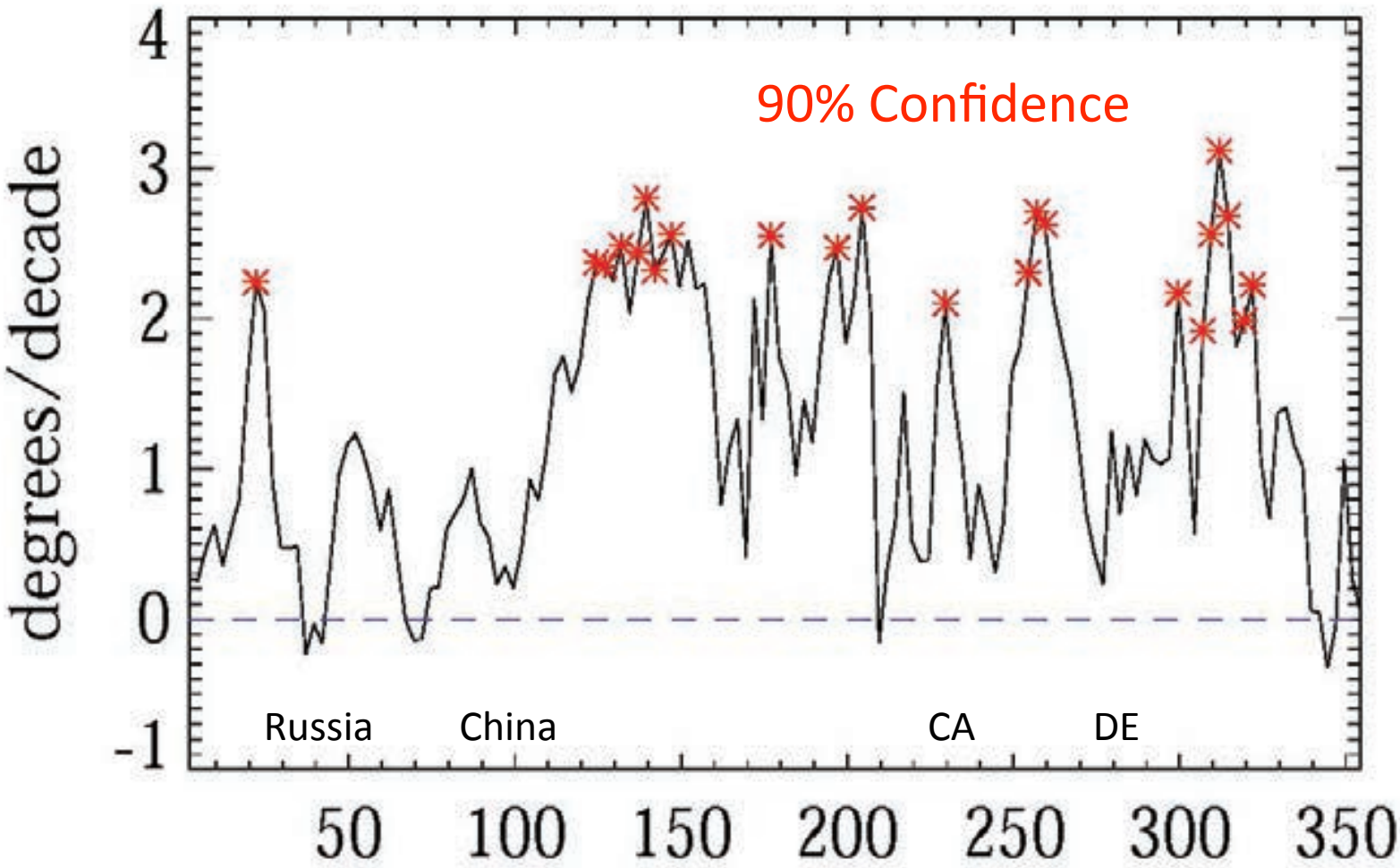




Figure 1. (a) Atmospheric conditions during Hurricane Sandy's transit along the eastern seaboard of the United States, including the invasion of cold Arctic air into the middle latitudes of North America and the high-pressure blocking pattern in the northwest Atlantic. (b) After the convergence of tropical and extra-tropical storm systems, the hybrid Superstorm Sandy made landfall in New Jersey and New York, bringing strong winds, storm surge, and flooding to areas near the coast and blizzard conditions to Appalachia.

Greene et al. (2013)

# Trend of jetstream "waviness" (Oct.-Dec.)

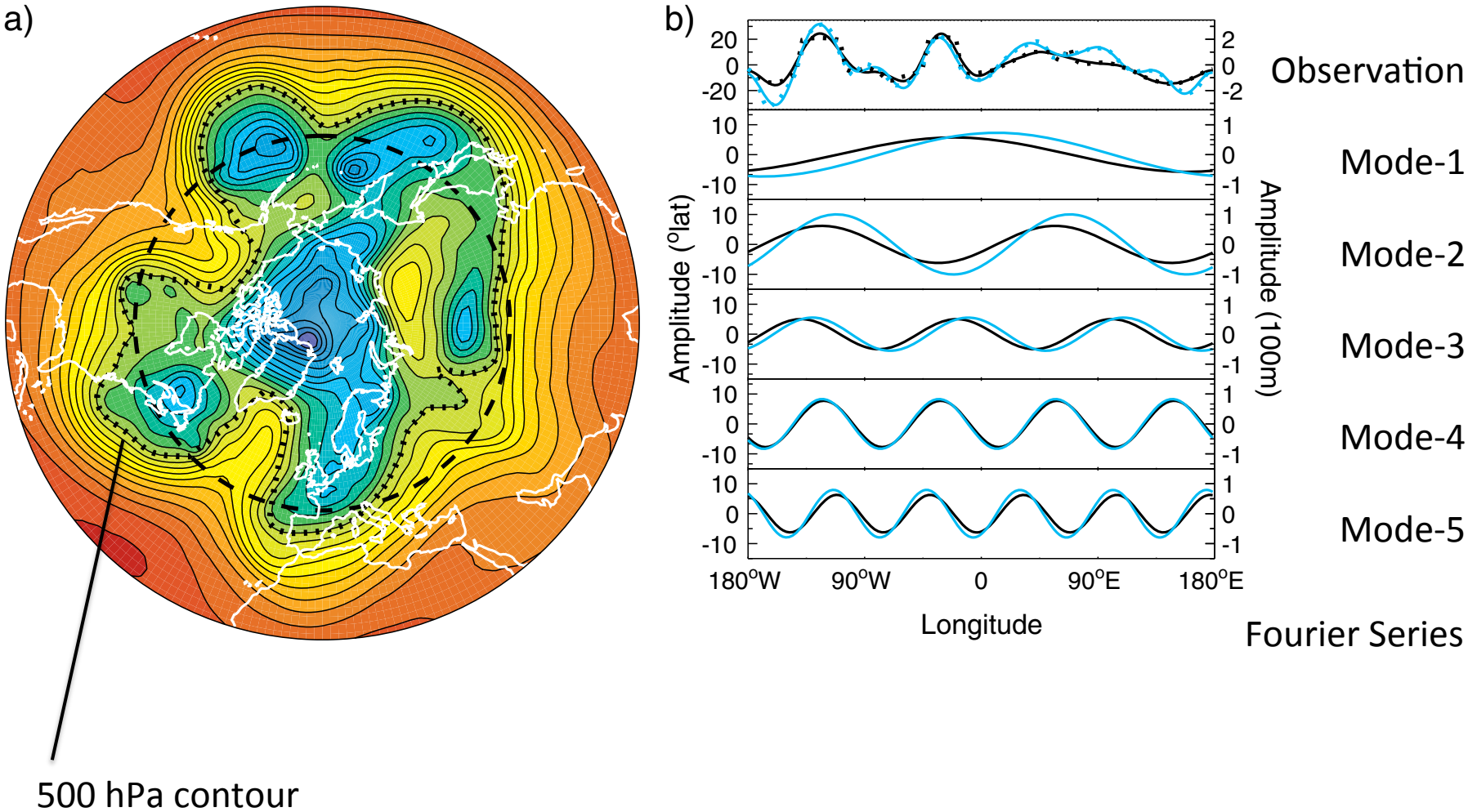



Longitude

Francis (2014)

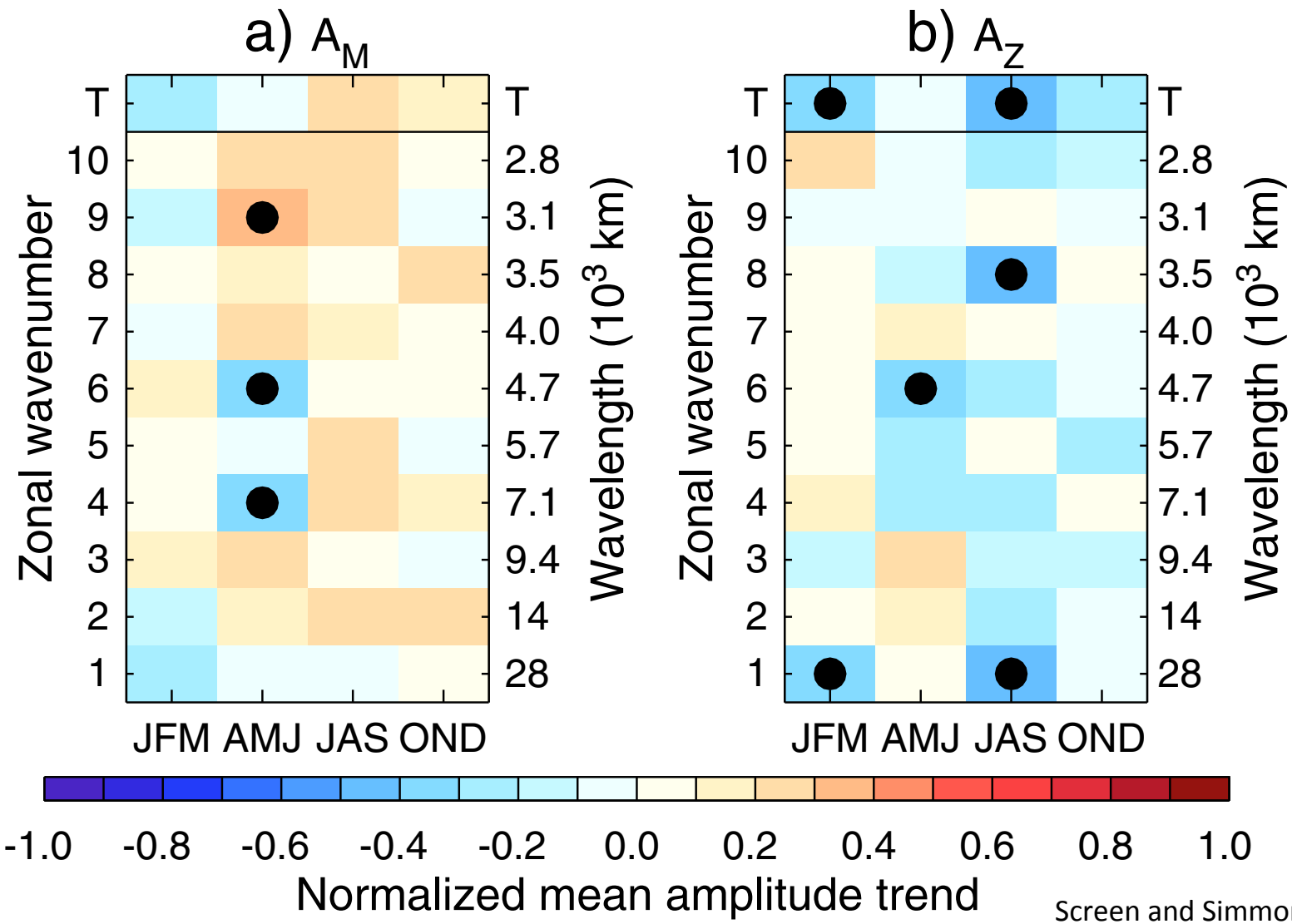
# Atmospheric Rossby Wave Amplitude Measures

SCREEN AND SIMMONDS: ARCTIC WARMING AND MID-LATITUDE WEATHER




Screen and Simmonds (2013)

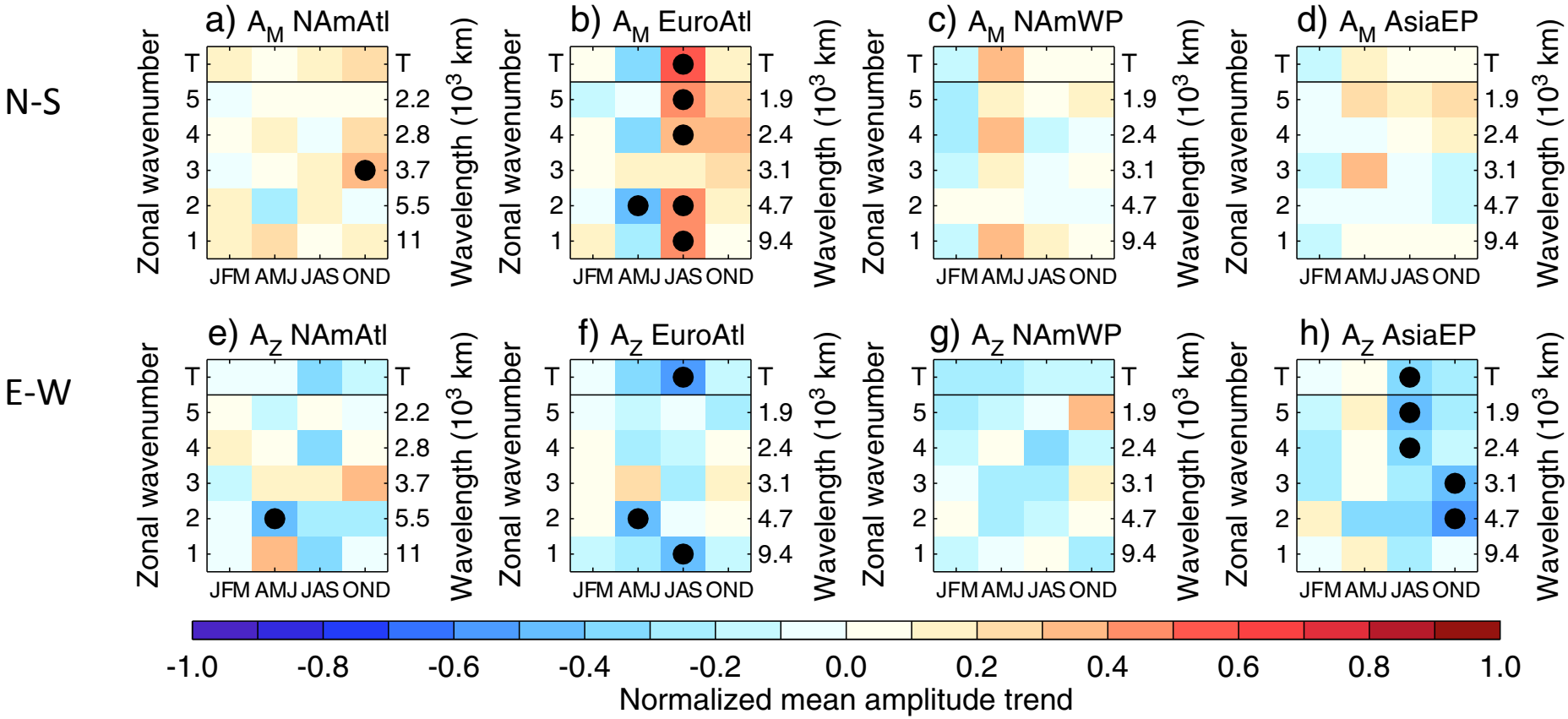
# Atmospheric Rossby Wave Amplitude Trends (95% confidence)




Screen and Simmonds (2013)

# Atmospheric Rossby Wave Amplitude Trends

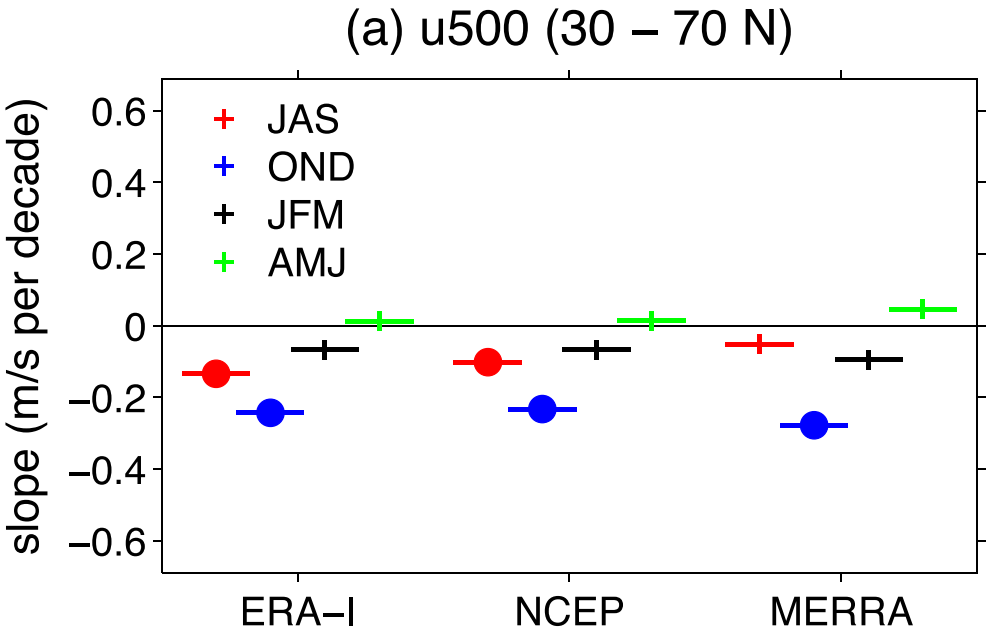
Amplitudes:



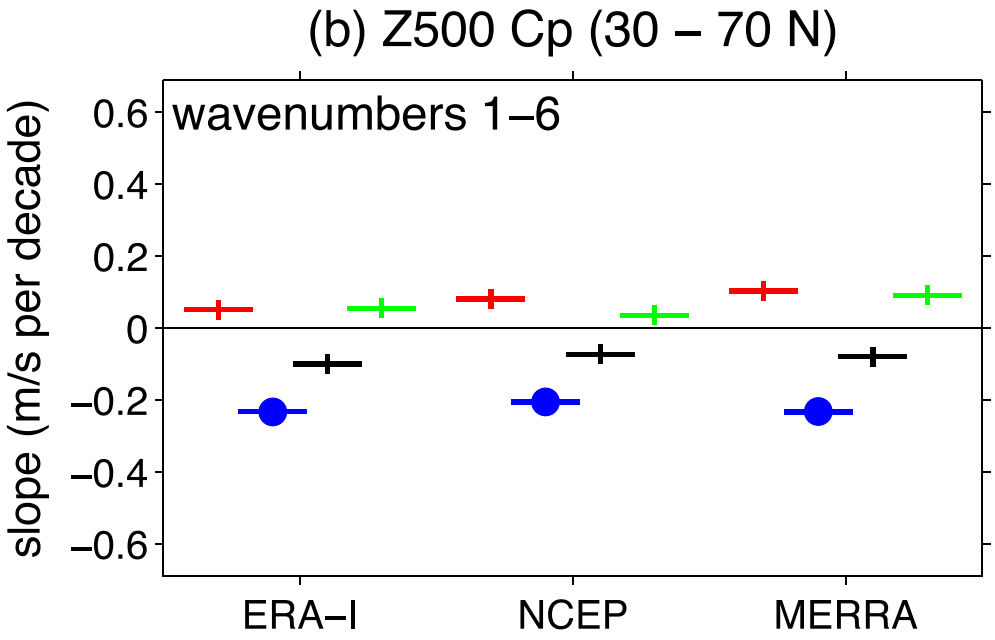

Screen and Simmonds (2013)

# Polar Amplification
# Extreme mid-latitude weather events more likely?

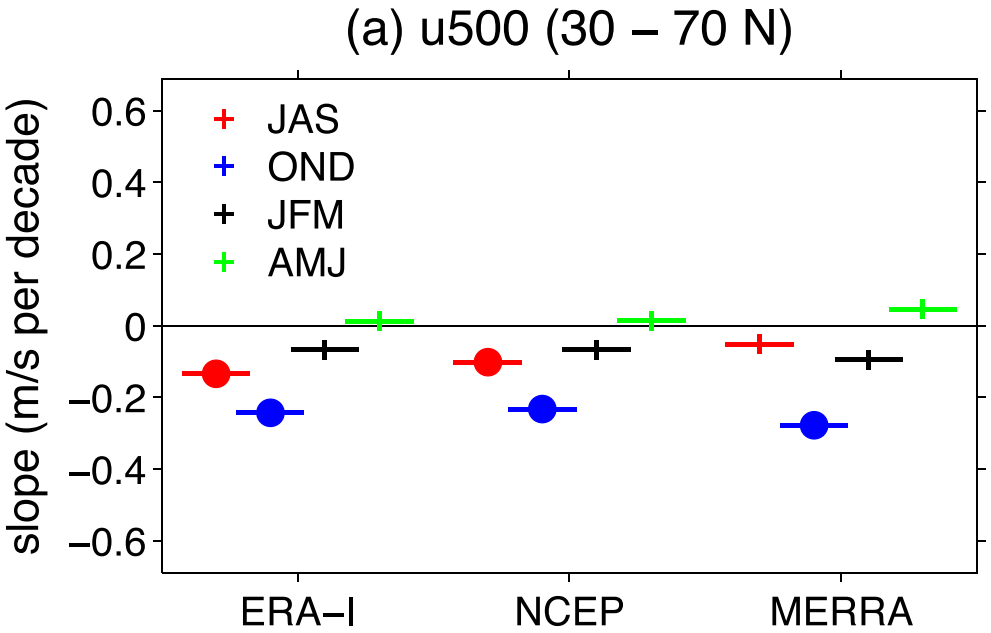
| | |
|---|---|
| Less sea ice, more open water | ✔ Yes |
| --> More heat flux from ocean to atmosphere | ✔ Yes |
| --> Arctic air warms faster than sub-Arctic air | ✔ Yes |
| --> Weakens N-S pressure gradient and E-W jetstream | ✔ Yes |
| --> Weaker jetstream has larger N-S meanders | ? maybe |
| --> Larger meanders move more slowly | ? maybe |
| --> Extreme weather events more frequent | maybe not |



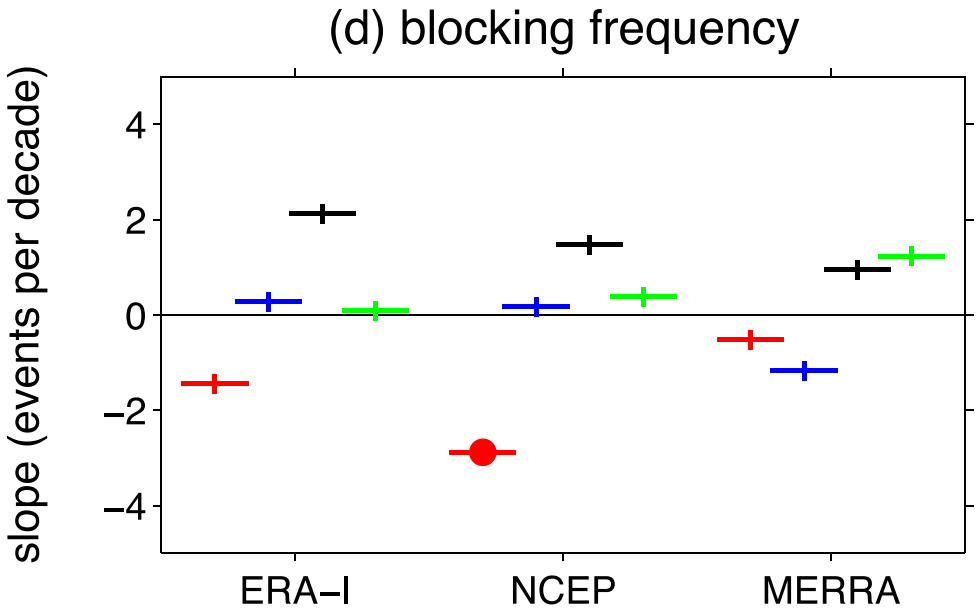

# Atlantic Region
# 30-70 N latitude



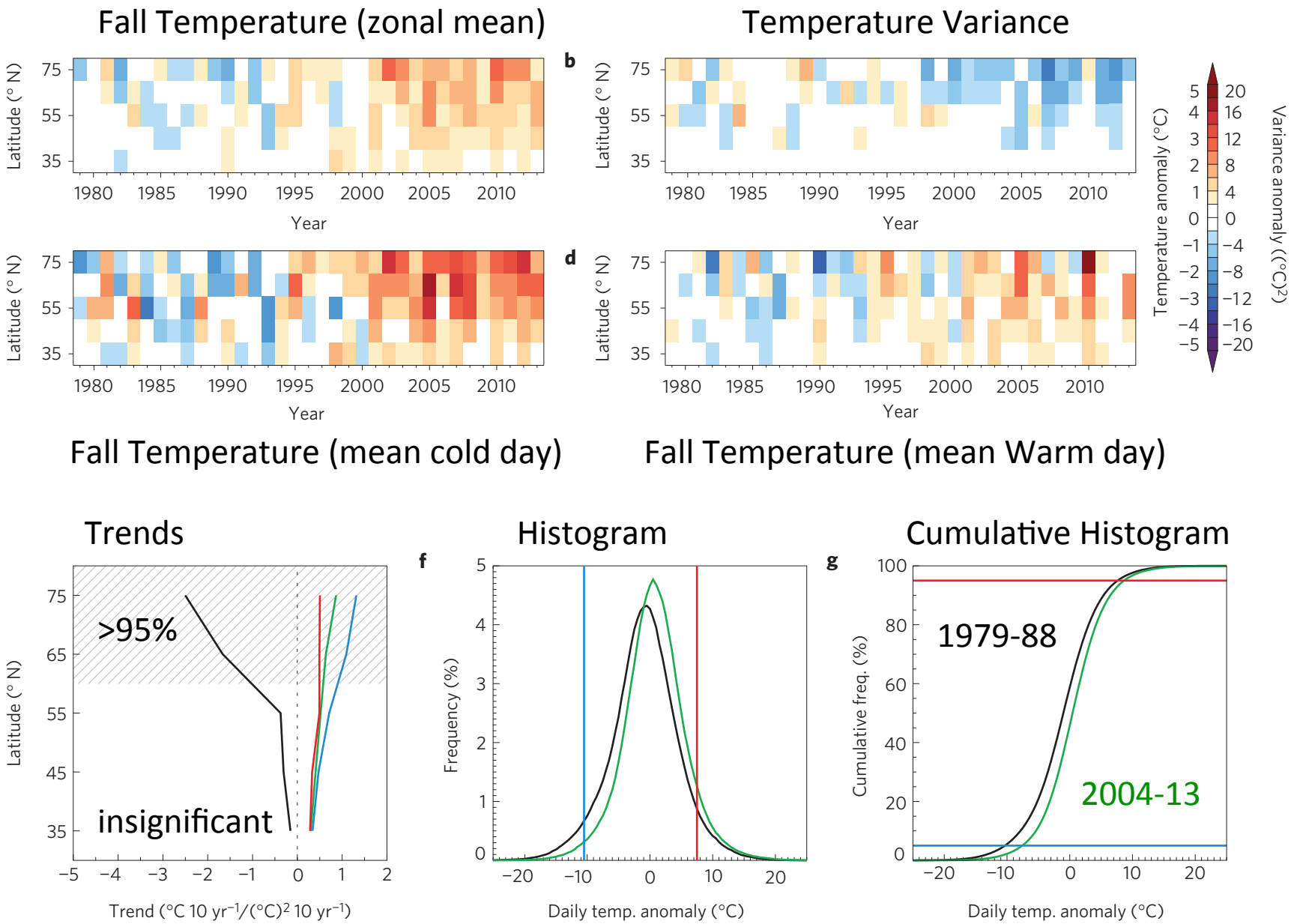

Barnes (2013)




# Atlantic Region
# 30-70 N latitude




Barnes (2013)

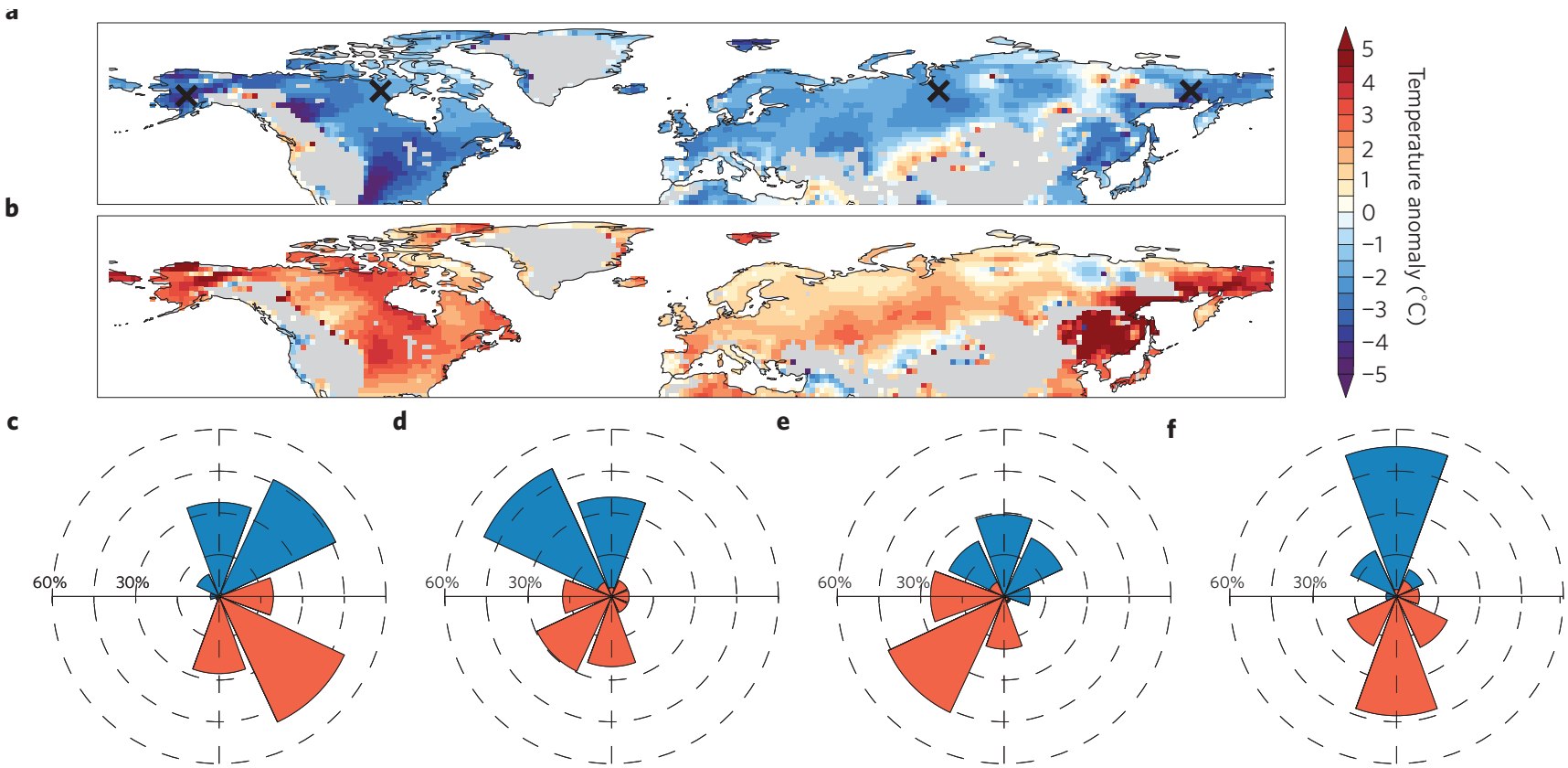



Linear Trends and Distributions: ***Temperature increases, but variance decreases***

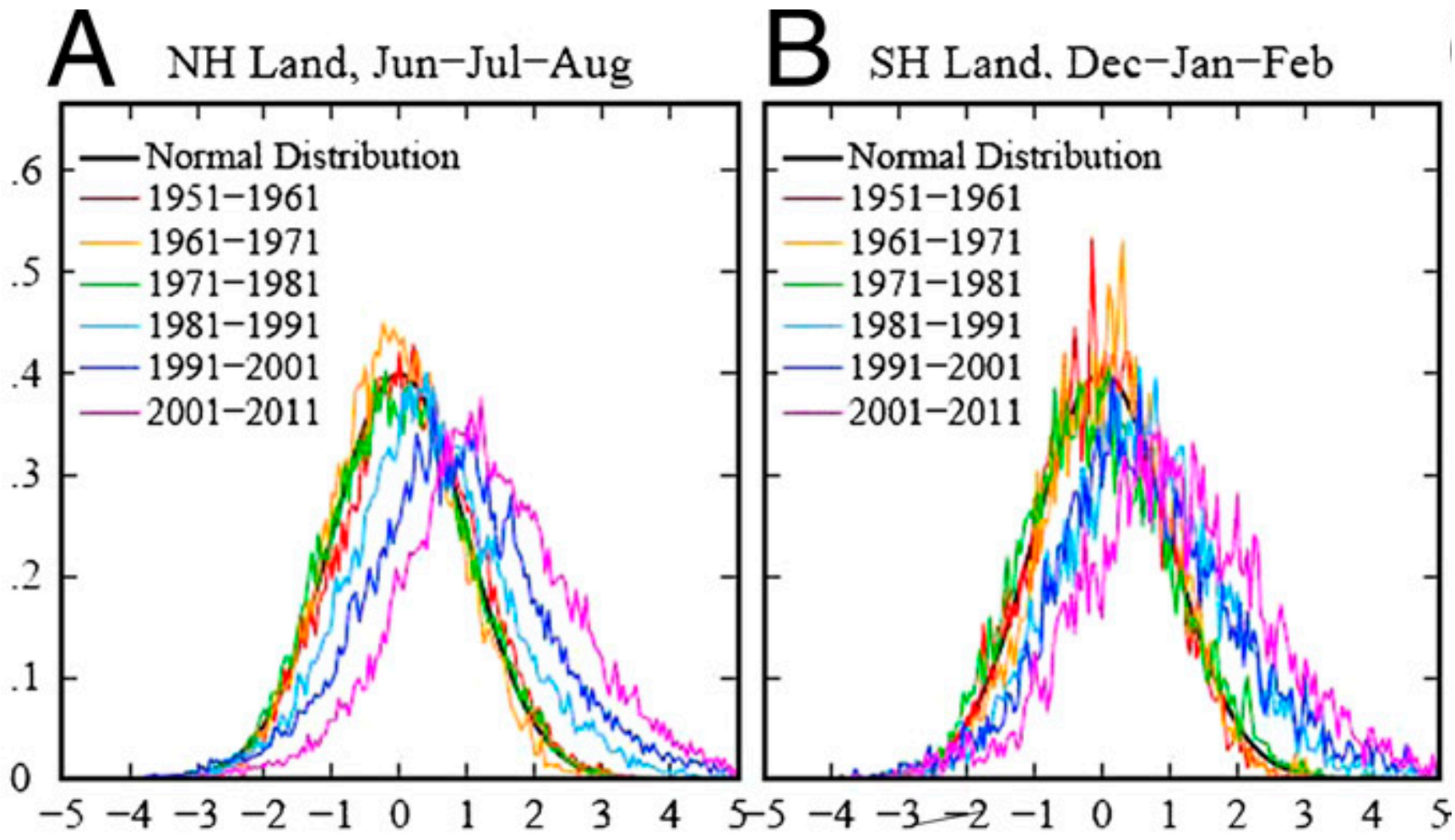
Screen (2014)

# Mean fall daily 925 hPa temperature anomaly

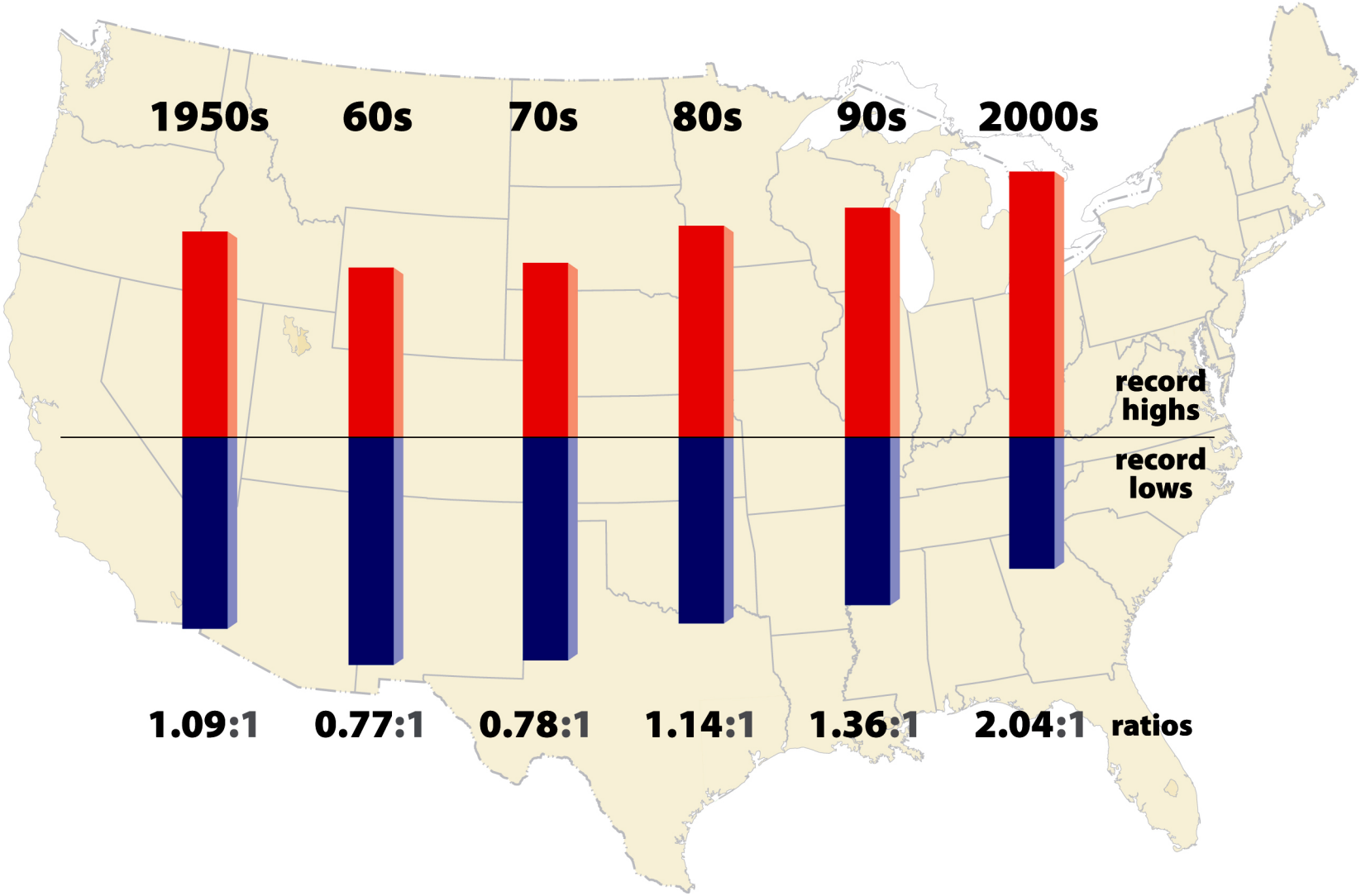
(a) during northerly winds
(b) during southerly winds




Screen (2014)

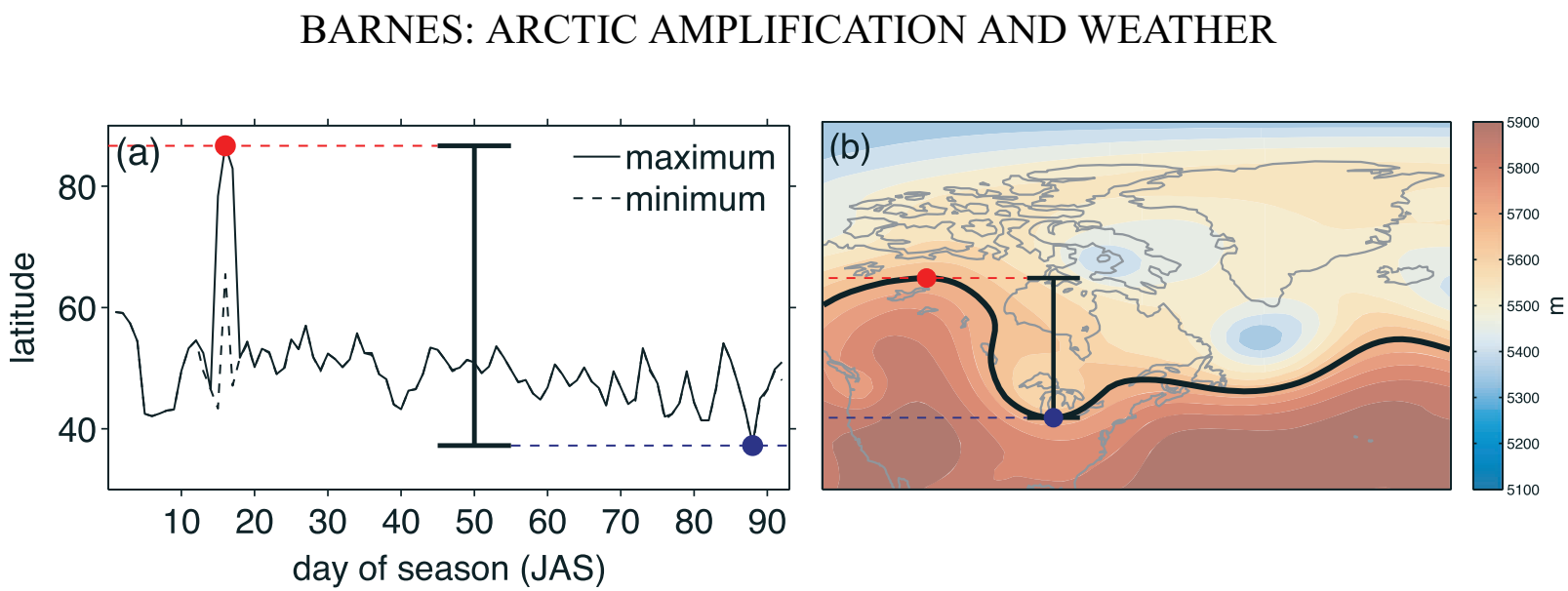



Hansen et al. (2012)

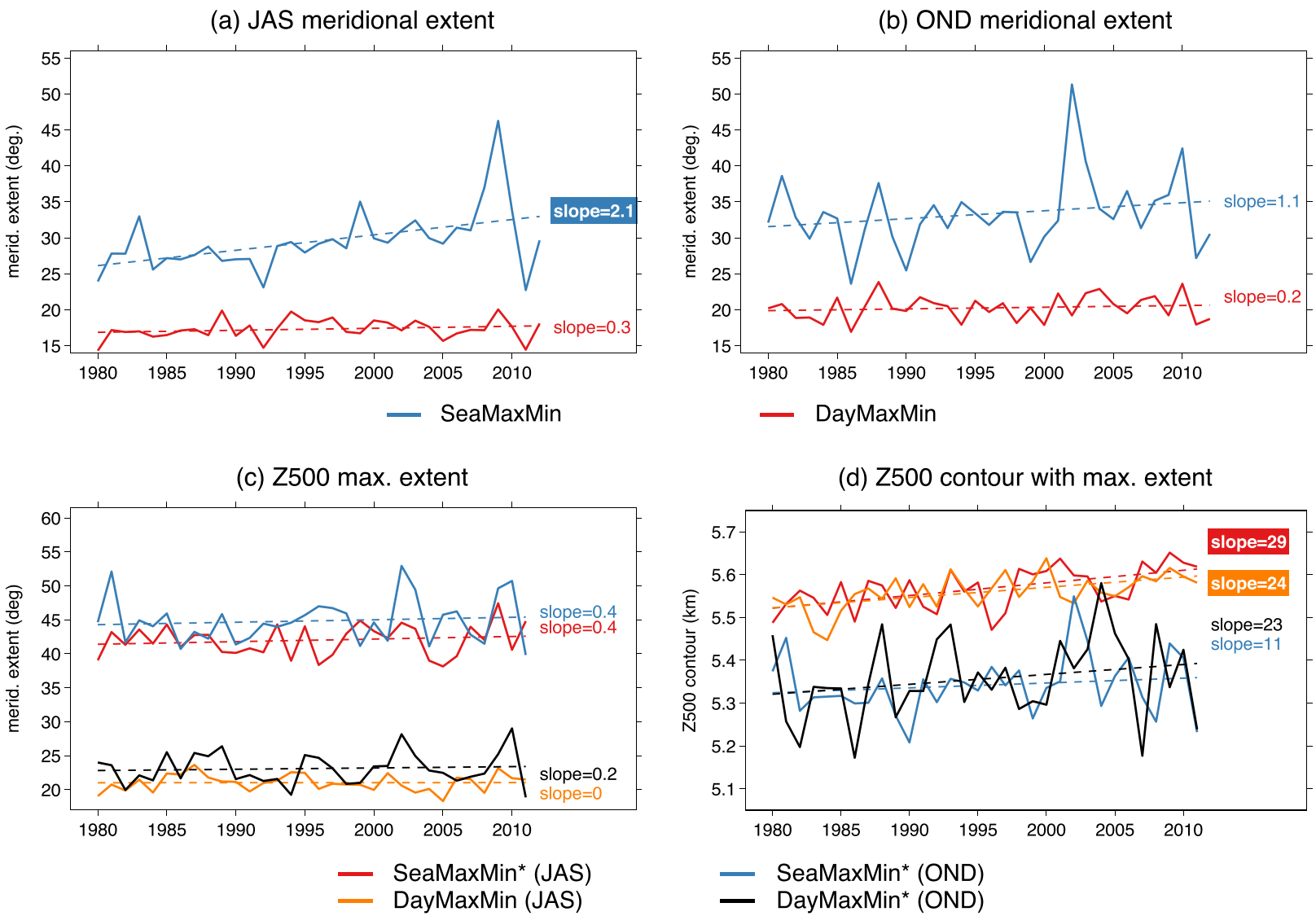



Meehl et al. (2009)

# How to define a metric of atmospheric Rossby waves?




Barnes (2013)


(a) JAS meridional extent
merid. extent (deg.)
slope=2.1
slope=0.3
SeaMaxMin
(b) OND meridional extent
merid. extent (deg.)
slope=1.1
slope=0.2
DayMaxMin
(c) Z500 max. extent
merid. extent (deg)
slope=0.4
slope=0.4
slope=0.2
slope=0
SeaMaxMin* (JAS)
DayMaxMin (JAS)
(d) Z500 contour with max. extent
Z500 contour (km)
slope=29
slope=24
slope=23
slope=11
SeaMaxMin* (OND)
DayMaxMin* (OND)

Barnes (2013)